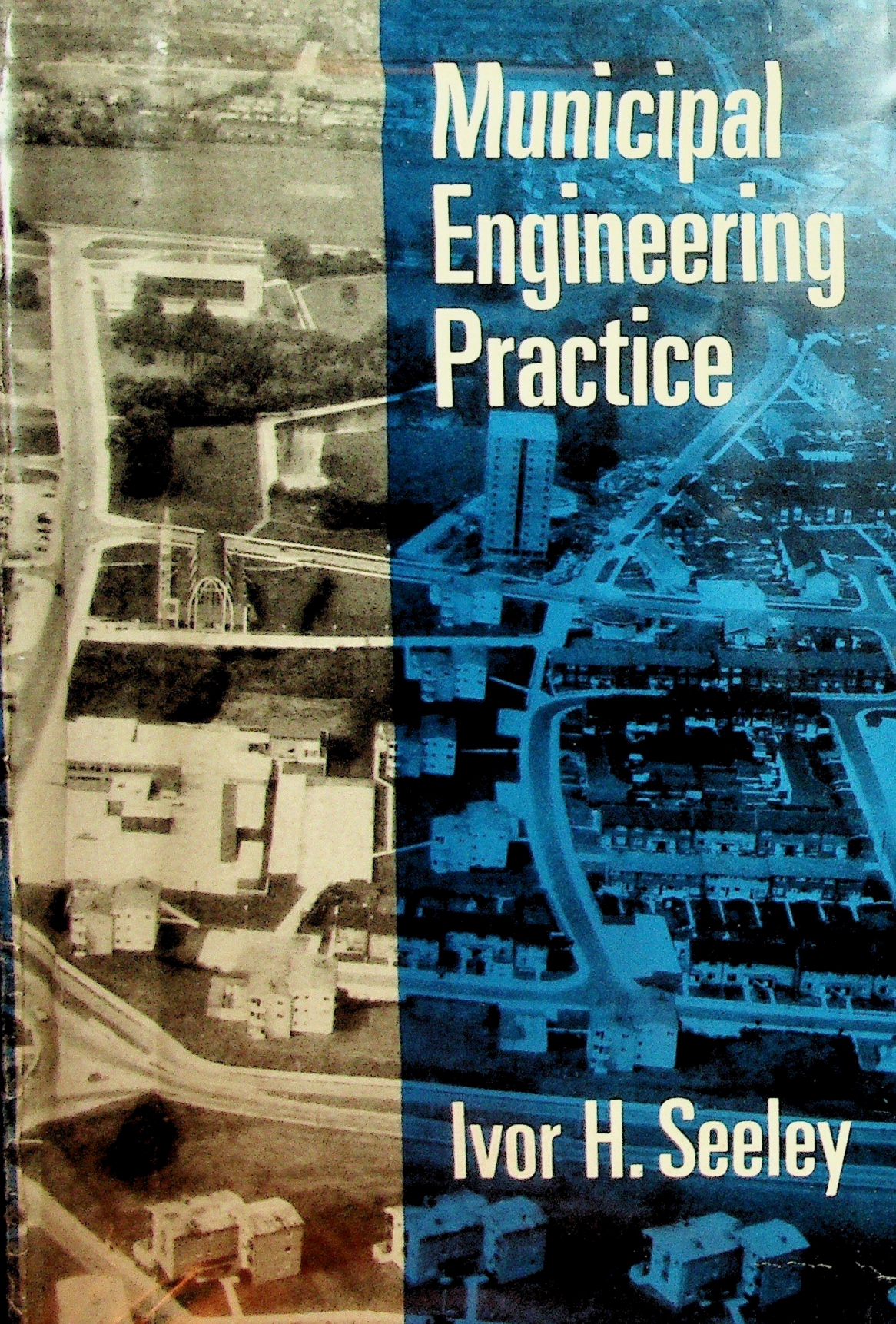




Municipal Engineering Practice

Ivor H. Seeley

Municipal Engineering Practice

by Ivor H. Seeley

This is a comprehensive handbook covering all aspects of municipal engineering in town and country. It includes chapters on general subjects such as surveying and construction, chapters on particular subjects such as sewage disposal, numerous line and photographic illustrations, and, at the ends of the chapters, extensive references to more detailed information.

Municipal engineers will find it a most useful book, and for members of allied callings, such as civil engineering contractors, architects, surveyors, and innumerable suppliers of materials, it is valuable as showing the relation of their own work to other aspects of public service engineering. It is intended also for the use of those studying for degrees or diplomas in civil engineering, and aiming at corporate membership of the Institution of Municipal Engineers or the Institution of Civil Engineers.

The author, at present Senior Lecturer in Quantity Surveying at Nottingham College of Technology, has had extensive experience with various local authorities and with consulting civil engineers, and is well known for his successful books on *Building Quantities* and *Civil Engineering Quantities*.

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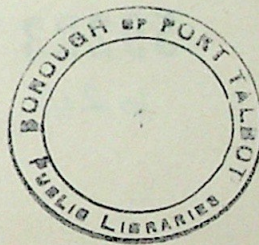
By the same author

Building Quantities Explained
Civil Engineering Quantities

Municipal Engineering Practice

IVOR H. SEELEY

B.Sc., M.A., C.Eng., M.I.Mun.E., F.R.I.C.S., F.I.Q.S.
Chartered Engineer and Surveyor



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This book is dedicated to my father-in-law

J. R. BENSLEY, EsQ., J.P., C.A.

*in recognition of his long and valued service as a local
authority member*

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Preface

THIS book is designed to meet the needs of the young municipal engineer, in whatever part of the world he may be; but much of its contents should prove useful to his more senior colleagues, who require a handy book of reference. In addition, members of allied professions such as architects, surveyors, town planners and public health inspectors, may find much of interest and value within its pages.

It should prove particularly helpful to students studying for the examinations of the Institutions of Municipal and Civil Engineers and the Council of Engineering Institutions, and for degrees and diplomas in civil and municipal engineering.

The author's intention is to provide information on all the many aspects of municipal engineering work, including design, construction, maintenance and administration. The text includes detailed information on surveying for and setting out municipal engineering works, highway and traffic engineering, main drainage and water supply, public cleansing, and housing and town and country planning. It is illustrated with numerous drawings and a selection of plates, showing examples of constructional work. Latest developments and techniques are also described in some detail. Numerous references are given at the end of each chapter, to direct the reader to sources of more detailed information on particular topics.

Some may argue that a book of this type will be of decreasing value as specialists begin to perform an increasing number of municipal engineering functions. This process could hardly have universal application and the specialists would still require to be well-informed on the work of their fellow colleagues in other branches of the profession. Furthermore, every municipal engineer is accustomed to giving advice on a wide range of technical matters, and this calls for a broad knowledge and experience of the technical aspects of municipal work.

*Nottingham,
Spring 1967*

I. H. SEELEY

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CHAPTER ONE

Functions and Requirements of the Municipal Engineer

FUNCTIONS OF THE MUNICIPAL ENGINEER

THERE can be very few professions which offer such an interesting and satisfying career as municipal engineering. The municipal engineer is responsible for the provision and operation of a variety of services which are of vital concern to every member of the community. Many of these services affect the citizen's health, well-being and general convenience.

The work undertaken by the municipal engineer includes the design, construction and maintenance of highways and bridges, sea defence works, sewers and sewage disposal works, water mains and waterworks, refuse destruction and composting plant, municipal car parks, schools, flats, houses and other public buildings, public parks, playing fields, swimming pools, etc. This list represents some of the major projects with which the municipal engineer may be concerned, but his functions vary with the type of local authority by whom he is employed.

For instance, the engineer of a county borough will probably be responsible for the majority of the services listed, although only those county boroughs situated on the coast will be concerned with sea defence works, and responsibility for water supply sometimes rests with water boards, representing a number of local authorities or private companies. At the other end of the scale, the rural district council is primarily concerned with the provision and maintenance of local authority housing; sewers and sewage disposal works and possibly works of water supply; the collection and disposal of refuse; and the administration of building and town and country planning regulations. In recent years much more importance has been attached to subjects

such as town planning, town centre redevelopment and traffic engineering, in which fields municipal engineers have a vital role to play.

The municipal engineer is essentially a technical officer, although most chief officers and their deputies undertake a vast amount of administrative work. His job normally entails a considerable amount of out-door work and he comes into contact with all sections of the community. There is little doubt that he receives a great deal of satisfaction from the constructional works for which he is responsible.

The municipal engineer is generally fortunate to see a job through from inception to completion. Thus, he will usually survey the site of the project; design the scheme, which generally involves the preparation of drawings, specification, bill of quantities and often an estimate of probable cost; obtain, examine and report on tenders and set out and supervise the constructional work, including the periodic measurement and valuation of the work as executed. Alternatively, the work may be carried out by the local authority's direct labour organisation, when the municipal engineer will also be responsible for organising the job, ordering materials, checking costs and progress, etc.

The work designed by the municipal engineer is almost invariably subject to approval by a committee of the local authority and sometimes by the full council itself. The committee will require full particulars from the municipal engineer, usually in the form of a report supported by preliminary drawings and an estimate of the probable cost of the work. The report will outline the need for the scheme and give a broad description of the proposals. The municipal engineer must also be prepared to answer any questions on the scheme which members of the committee may raise.

Apart from the design and supervision of the execution of new work, the municipal engineer is also very much concerned with the maintenance and operation of the existing services under his control. For instance, much highway work carried out by a local authority is directed at the maintenance, repair and minor improvement of its roads, paths, grassed areas, gullies, street lighting, etc. The periodic cleansing of paved surfaces, surface dressing of carriageways and emptying of gullies must be undertaken, if these services are to satisfactorily meet the needs of the public.

On occasions, maintenance or repair work can develop into an emergency operation under extreme conditions. Typical examples being the clearing of vast quantities of snow from roads, repair work to blocked sewers or burst water mains, carrying out flood prevention work or dealing with roads which have been blocked by fallen trees, as a result of severe gales. The municipal engineer must be ready to organise these

classes of work at any hour of the day or night, often under very trying weather conditions. This type of work is very arduous but can be very rewarding, but not financially.

QUALITIES REQUIRED OF A MUNICIPAL ENGINEER

There are a number of basic qualities which any entrant to the municipal engineering profession should possess, and these are outlined in the following paragraphs.

(1) He must be keen on mathematical and scientific subjects and have secured a reasonable standard in these subjects at school. They form the basis of much of the design work which is carried out in a municipal engineer's office.

(2) It is highly desirable that he should have a constructive and enquiring turn of mind and be interested in the working of machinery, and the building and other operations that take place in his vicinity.

(3) He should be happy when working out-of-doors, even under adverse weather conditions, as municipal engineers are often called upon to organise work under the worst possible climatic situations.

(4) The ability to get on well with other people is a decided asset for persons wishing to enter this profession.

A municipal engineer comes into contact with many different classes of people during the course of his work and he must be able to appreciate their problems and maintain good relations with them. The people with whom he comes into contact include contractors and their employees, the outdoor force of his own department, members of the public, who can sometimes be very troublesome, members of his own local authority and officials of other departments of his authority. They constitute a wide body of people with differing outlooks, interests and requirements, and the municipal engineer must be able to work smoothly with all of them.

On many occasions a team effort is needed if the best results are to be achieved. There must be maximum co-operation and mutual confidence in one another if all the problems that arise on jobs are to be overcome satisfactorily, and the work is to proceed smoothly and efficiently.

In later years, possibly as a chief officer, the municipal engineer needs to be endowed with a good measure of tact, patience and understanding in order to withstand successfully the round of council and committee meetings which he will be called upon to attend.

METHODS OF TRAINING

There are three principal methods of training for entry to the municipal engineering profession:

- (1) University—full-time course.
- (2) College of Technology—sandwich course.
- (3) Articled pupilage or as an assistant under agreement to a municipal engineer.

Each of these three methods will be considered in some detail, although the choice may often be dictated by the circumstances prevailing in a particular locality. In all cases the intending entrant to the profession must have attained the current entry requirements (these are at present five passes in the General Certificate of Education including two 'A' levels).

(1) University

One method of entry to the profession is to take a three-year course of full-time study at a university for a degree in civil or municipal engineering. This provides excellent technological education which is followed by a further two years training in the office of a municipal engineer. The young engineer is designated as a 'graduate assistant' during this 2-year period, when he receives good practical training in municipal engineering work and receives a reasonable salary at the same time.

(2) College of Technology

Many Colleges of Technology (mainly regional colleges) offer sandwich courses leading to the award of college diplomas, which may give exemption from the first two parts of the examinations of the Institutions of Civil and Municipal Engineers respectively. Furthermore, some regional colleges are awarding B.Sc. degrees in civil engineering, under the auspices of the C.N.A.A., usually based on sandwich courses.

Sandwich courses may take several different forms. One form commonly operated at present is where the student spends 6 months at the college, and 6 months in industry (e.g. in a municipal engineer's office) for each of 4 years, and he is required to sit examinations at the college at the end of each 6 months course.

Another form of sandwich course, which is of more recent origin, is also spread over 4 years, but the student spends 2 full years in the college (8 to 9 months a year) with a short 'appreciation period' in

industry between them. This is followed by a full year in industry (14 to 15 months), when the student will secure useful practical experience, followed by one further year in the college to complete his study of the more professional type subjects.

It will be seen that the courses conducted by the colleges of technology aim at securing a happy combination of technological education and practical training, and these should become an increasingly popular method of entry to the profession, as the distribution of and facilities offered by these colleges improve.

(3) Articled Pupilage

The third method of entry to the profession was the normal method until quite recent years. The entrant serves under a municipal engineer as an articled pupil or assistant under agreement for a minimum period of three years. In this way the pupil or assistant receives practical training from the outset, unlike attendance on a university course where little or no practical training is received during the 3-year period of the course.

This method of training has the great disadvantage that most of the assistant's study will have to be undertaken during his spare time. He will be permitted to attend the nearest technical college for one day per week for purposes of study, provided there is a suitable college within a reasonable distance of the office, but this is not always the case.

Even where a suitable college is available, it is generally going to be much harder work and will take a longer period to qualify. In cases where technical college facilities were not available, it had generally been the practice in the past for students to study with the aid of correspondence courses. The Council of the Institution of Municipal Engineers announced in 1964 that no help would be given to candidates for the Part I and II examinations seeking information on correspondence courses, and that these candidates would be told that correspondence courses for these examinations are unsuitable and are likely to lead to failure.

Some correspondence colleges have rendered extremely good service over many years and will still be able to help some overseas students. No doubt the Institution's statement was prompted by the large number of courses now available at technical colleges, the superior facilities that they offer to students and the need to keep abreast of progress and make use of latest teaching methods and techniques.

All articled pupils and assistants under agreement enter into indentures with municipal engineers approved under the Joint Scheme for the Training of Municipal Engineers (see reference 1 at the end of this

chapter). This scheme is administered by a joint committee of the Institutions of Municipal and Civil Engineers. Only those chief officers of local authorities who are corporate members of one or both of these institutions and are registered under the scheme, can provide approved practical training for graduate assistants, articulated pupils or assistants under agreement. The number of trainees that can be taken in a particular office is fixed according to the size of the local authority.

The emphasis on particular aspects of practical training will vary between the offices of different types of local authority. For instance, a trainee in a county surveyor's office will receive mainly highway experience, whilst another in a large borough will receive experience in large-scale works and yet another, with a comparatively small urban district, will be mainly concerned with small-scale works but will have the advantage of closer contact with the chief officer.

The well illustrated booklet *Municipal Engineering as a Career* (2) contains details of a typical programme of practical training, as follows:

<i>Type of work</i>	<i>Graduate Assistant</i>	<i>Articled Pupil or Assistant under Agreement</i>
Engineering Design (Drawing Office)	6 months	12 months
Planning and Development	5 months	5 months
Surveying (Practical)	—	2 months
Direct Works (Highways Organisation)	4½ months	6 months
Contract Work	4 months	6 months
Building Control	1 month	1 month
Corporation House Construction	1 month	1 month
Sewage Disposal Works (operational)	1 month	1 month
Administration and Cost Accountancy	2 weeks	2 weeks
Annual Leave	4 weeks	6 weeks
Totals	2 years	3 years

This represents a well-considered and comprehensive scheme of practical training, combining drawing office practice with experience in the main works sections of the municipal engineer's organisation. The articulated pupil or assistant under agreement has been allocated 2 months for practical surveying work, whereas this does not feature in the shorter scheme of training for the graduate assistant who will, presumably, have received adequate tuition in practical surveying as part of the university degree course. Papers describing deficiencies in the present methods of training municipal engineers are listed in references 5 and 6 at the end of this chapter.

QUALIFICATIONS

The principal qualifications in municipal engineering are university degrees in civil or municipal engineering and corporate membership of the Council of Engineering Institutions and the Institutions of Municipal and Civil Engineers respectively. All the latter bodies are chartered institutions. The Council of Engineering Institutions is a federation of thirteen chartered engineering bodies and corporate members are designated 'chartered engineers' (C. Eng.). There are also specialist qualifications in certain specific aspects of municipal work such as town planning, highway engineering, traffic engineering, sewage purification, water engineering and public health engineering.

The Institution of Municipal Engineers is the principal professional body concerned with the whole range of municipal engineering activities. Its foundation probably dates back to the establishment of The Association of Municipal and Sanitary Engineers and Surveyors in 1873. This Association was incorporated in 1890 and its title was changed to The Institution of Municipal and County Engineers in 1908. In 1948 the Royal Charter was granted and the name of the body was again changed to The Institution of Municipal Engineers.

The Institution's objects are 'The promotion of the science of engineering and cognate subjects as applied to all or any of the duties imposed upon or services undertaken by local authorities and other public undertakings for the benefit of the community, with the object of securing the highest degree of efficiency in the discharge of such duties and the operation of such services'.

An annual conference has been held every year since 1874, at which technical papers are presented and discussed. In addition over 150 district meetings, including summer schools and study courses are held each year. The total membership of the institution in 1965 exceeded 8,500.

The Arms of the Institution are particularly instructive in that they seek to express, in heraldic forms, the main interests and activities of the Institution and its members. The white and green 'field' or background represents water and land (the wavy white bars indicating pure water supply and unpolluted rivers and the intervening green sections represent parks, open spaces and recreation grounds). All signify 'Amenity'.

A black division down the centre represents a highway and bridges. On this black section is a winged wheel (traffic and machinery) and a torch (Institution's educational work and public lighting). These signify 'Progress'. There is also a mural crown, masoned and battlemented like a

city wall (emblem of local government and building construction). This signifies 'Stability'. The orderly layout of land, water and highway on the shield is symbolic of town and regional planning.

The examination of the Institution of Municipal Engineers leading to corporate membership and the designation 'Chartered Municipal Engineer', is split into three parts.

Part I covers engineering theory—engineering drawing, mathematics, applied mechanics, principles of electricity, heat, light and sound, strength of materials and theory of structures.

Part II covers practical professional subjects—surveying and site investigation, highway engineering, engineering design and building construction, sewerage, sewage disposal, public cleansing, highway planning, traffic engineering and town planning practice.

Part III consists of written examinations in law and administration, a report on work done during training and a professional interview (3). This book is primarily concerned with the subjects contained in Parts II and III of the Institution's examination.

In addition, the Institution has established 3 diplomas in Organisation and Administration, Traffic Engineering and Town Planning respectively. The Part I and II examinations of the Institution of Municipal Engineers will be replaced in the future by examinations conducted by the Council of Engineering Institutions.

CONDITIONS OF SERVICE

The conditions of service for engineers and surveyors to local authorities are issued by the Joint Negotiating Committee for Chief Officers of Local Authorities (4).

The engineer and surveyor to a local authority, be he a city engineer, borough engineer, urban district or rural district engineer, is the executive and administrative head of the department of which he is the chief officer. He is responsible for his department to the council through the appropriate committees. He undertakes to devote his whole time to the work of the council and not to engage in any other business or to take up any other additional appointment without the express consent of the council.

Salaries of chief officers are paid in accordance with the recognised current salary scale, which is largely dependant upon the population within the boundaries of the local authority. For each population range, e.g. 30,000–60,000, a number of salary scales can be operated. This permits some measure of flexibility and enables each local authority to

have regard to the conditions affecting the particular post, when fixing the salary scale.

For instance, the functions of local authorities and the corresponding duties and responsibilities of chief officers vary with different classes of local authority. Furthermore, local conditions vary tremendously throughout the country, such as the high cost of living in the London area, the large seasonal influxes of visitors received by holiday resorts and inland spas which are not reflected in population figures and the extra duties devolving upon the chief officers of towns engaged in planned expansion. The variations in salary scales give local authorities the means to make allowance for these varying factors. In addition to salary, municipal engineers and various members of their staffs are paid car allowances for the use of private cars when carrying out their official duties, and these are usually calculated on a mileage basis.

RELATIONSHIP WITH COUNCILLORS AND LOCAL AUTHORITY OFFICERS

The municipal engineer acts as technical adviser to his council and its committees on matters coming within his jurisdiction. The majority of councillors are lay persons and cannot be expected to be fully familiar with all the technicalities of the services administered by the engineer. On the other hand, many elected representatives have a wealth of local knowledge and experience of the work of the local authority and are often very conscious of the needs of their particular area. They rely upon the engineer to advise them upon the practicalities and economics of various suggestions.

There is a great deal of team work carried out in the local government service. The engineer will often find it necessary to consult with other chief officers, such as the clerk and the treasurer or financial officer to the authority, when matters arise involving legal or financial aspects. Joint consultations are frequently held prior to the submission of detailed development and reconstruction schemes, and it is sometimes desirable to prepare a joint report, in which each of the officers affected produces a section of the report covering the matters for which he is responsible.

Proposals submitted by one chief officer can sometimes have repercussions in other departments of the same authority; for instance, a recommendation covering the regrading of staff. Difficulties of this kind are usually overcome by the town clerk or clerk of the council, acting as a co-ordinator and negotiating with other departmental heads and this method works quite well provided the clerk refrains from interfering in

the internal affairs of other departments. At least one of the larger authorities has appointed a town manager to give overall supervision to the affairs of the local authority, yet not, at the same time, to be responsible for the running of a department.

Day-to-day consultation will also need to take place between members of staff of the engineer's department and the staff of other departments in the exercise of their official duties. For instance, applications submitted to the engineer's department under building regulations can involve other departments, such as public health inspectors under food hygiene regulations, and petroleum officers when the storage of petroleum is involved. The treasurer's department is usually able to supply details of the current expenditure on any particular scheme at very short notice, as this information is invaluable to the engineer as he has to work closely within the estimates approved by his council.

Close co-operation between departments leads to a closer understanding of one another's difficulties and of better relations between officers. The establishment of branches of the National and Local Government Officers' Association (N.A.L.G.O.) throughout the country has also helped in this respect, as this Association draws its members from all branches of the public service and arranges residential courses and other functions where the different officers meet. Improved inter-relationship in this way must be beneficial to local authorities and make for greater overall efficiency and understanding.

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CHAPTER TWO

Surveying, Setting Out and Site Investigation

TYPES OF SURVEY

THE municipal engineer is required to carry out many classes of survey in connection with various aspects of municipal engineering work. For instance, he may have to make a survey of a site for a new sewage disposal works, a large housing estate or the line of a new road. A small land survey can be carried out satisfactorily with chain and tape, but a large area will probably call for the use of a theodolite and a traverse survey. When the redevelopment of large areas is being considered it is often advantageous to use aerial surveys.

All assistant engineers must be able to use a level speedily and accurately. Levels are required for almost every type of municipal engineering job—foundation and floor levels of buildings, invert levels of sewers and drains, road levels, finished levels of playing fields, etc.

It is sometimes necessary to carry out building surveys of existing buildings which are to be altered, improved or extended. These are usually carried out with a 100-ft linen tape and a 6-ft steel tape or wood rule.

LAND SURVEYS

Surveying Equipment

Relatively small areas of land can be conveniently surveyed using chain surveying methods. The essential equipment consists of a chain, linen or steel measuring tapes and ranging rods.

Chains are made up of a series of steel rods or links with flexible connecting links, and the engineer almost invariably uses the type

known as the engineer's chain in which there are 100 rods, each 1 ft in length. There is a brass handle at each end of the chain and a brass tab or tally at the end of each 10-link section of the chain—a tab with one tooth indicating a distance of 10 ft from one end of the chain and that with 2 teeth will be 20 ft along the chain.

The most common form of measuring tape is made of metallic linen and is wound by means of a brass handle into a leather case. It is made in varying lengths but the 100-ft tape is probably the most commonly used in municipal engineering work. Steel tapes are more accurate but are also more susceptible to damage.

Ranging rods are circular section wooden or light alloy poles, usually painted alternatively red and white or red, black and white, in 12-in. lengths and shod with a pointed steel shoe. Their primary use is for ranging out survey lines but they are also useful for the measurement of offsets.

Chain Surveying

The first step when surveying an area of land is to walk round the site and obtain the overall picture; at the same time determining the best position for survey lines, the location of obstructions and the amount of detail to be recorded. A digrammatic sketch is then made of the site in the field book, on which the position of the survey lines is indicated, together with the order and direction of chaining, as illustrated in Fig. 2. The order of chaining should enable the engineer to work in a logical and systematic order around the site, without having to walk a long distance from the end of one chain line to the start of the next.

The survey lines are located in close proximity to the boundaries to keep offsets as short as possible. The offsets are right-angled measurements from the survey lines to pick up the boundaries and other features. Offsets to hedges, fences, etc. are usually measured at regular intervals, such as 10 or 20 ft, with a rod or tape. Important features, such as buildings, trees, and changes of direction or intersections of boundaries usually have their positions fixed by ties, whereby the measurements form three

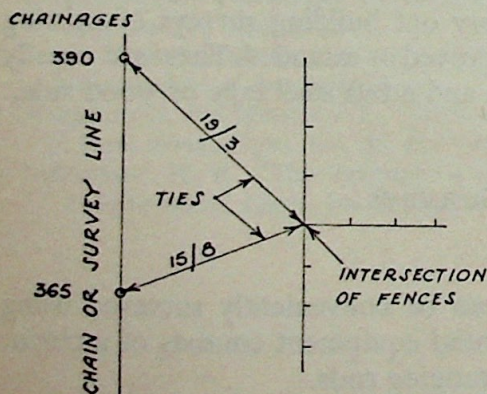
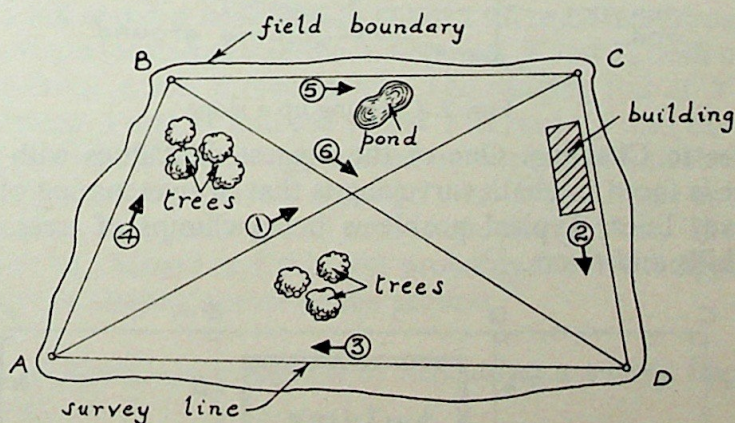
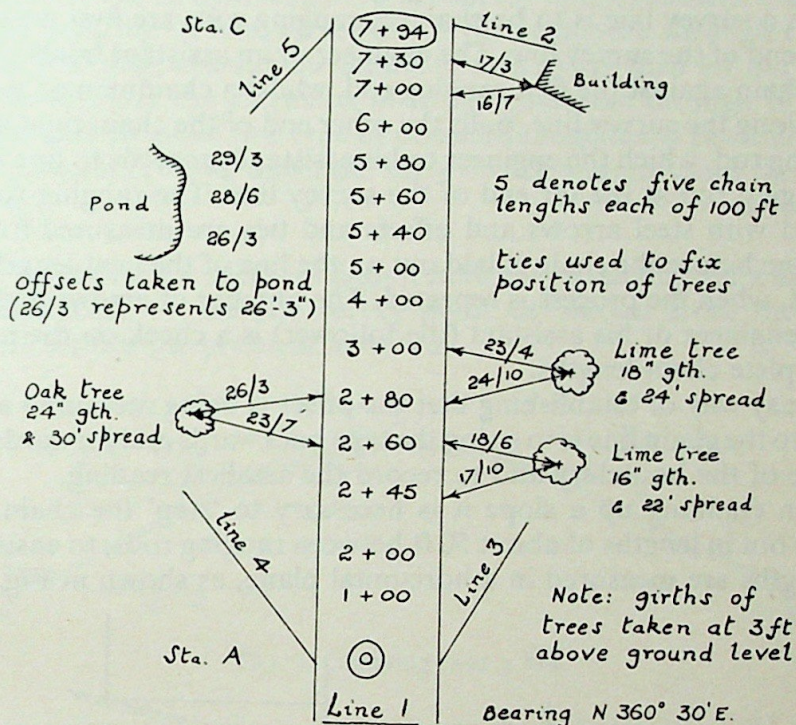


FIG. 1. Measurement of ties.

sides of a triangle as shown in Fig. 1. This latter process is more accurate than the offset method and avoids the need to have to set out a right-angle.

When deciding on the number and location of survey lines, considera-



NORTHGATE HOUSING SITE

18th march 19 -

FIG. 2. Field book entries.

tion must be given to the position of obstacles, such as trees, buildings, etc. and of the need to ensure that the survey lines are capable of being both plotted and checked. In the sketch in Fig. 2, line 1 forms the base to the two triangles and enables them to be plotted, whereas the diagonal line 6, provides a check on the lengths of the other survey lines.

When a survey line is to be chained, ranging rods are first positioned at each end of the survey line. The engineer or an assistant holds one end of the chain against the first ranging rod, whilst a chainman or assistant walks along the survey line, pulls the other end of the chain tight against a ranging rod, which the engineer or his assistant proceeds to line in with the ranging rod at the far end of the survey line. The ranging rods are replaced with steel arrows and offsets and ties are measured from the chain line before the chain is laid out on the line of the next length to be chained, when the process is repeated. The number of arrows picked up by the engineer or his assistant (the follower) is a check on the number of complete chain lengths.

An easy way of establishing that the offset is being measured at right angles to the chain line is to swing the tape backwards and forwards along the line of the boundary and to record the smallest reading.

When chaining up a slope it is necessary to 'step' the chain, often carried out in lengths of about 50 ft between ranging rods, to ensure that the lengths are measured in a horizontal plane, as shown in Fig. 3.

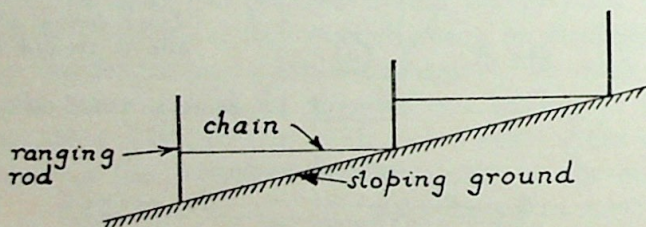


FIG. 3. Chaining up a slope.

Obstacles to Chaining. One of the biggest difficulties with which the engineer is faced in chain surveying is that of overcoming obstacles on the survey lines. Typical problems being clumps of trees, buildings, ponds, hills and rivers.

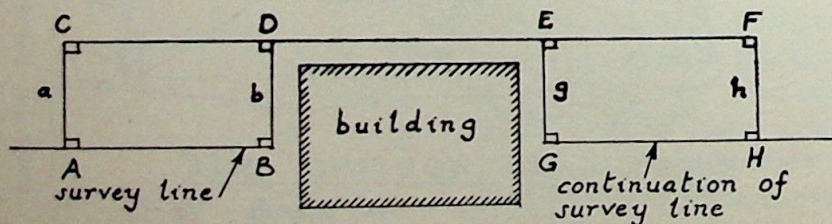


FIG. 4. Chaining around a building.

Buildings. Fig. 4 illustrates the usual method of measuring around a building which straddles a survey line. This method is equally applicable to clumps of trees, ponds and similar features.

The survey line AB in Fig. 4 is obstructed by a building and offsets a and b are set out at right-angles to the survey line, of sufficient length to clear the building. A new survey line is then extended through C and D past the building, and similar offsets (g and h) are then set out from E and F to produce the extension of the original line through G and H . It is desirable to avoid this type of obstacle altogether if possible, as the detour procedure slows down the survey work and increases the chance of error.

Hills. The engineer sometimes finds it necessary to chain over a hill when it is impossible to see one survey point or station from the other. Fig. 5 illustrates the problem involved.

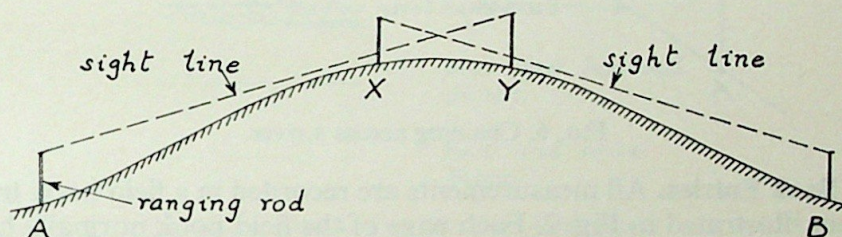


FIG. 5. Chaining over a hill.

Survey points or stations A and B are located on either side of the summit of a hill and it is necessary to chain a survey line between them. Ranging rods are located at intermediate points X and Y , both of which can be seen from A and B respectively. The ranging rod at X is then lined in between A and Y , and the rod at Y between B and the revised position of X . Next X is once again lined in between A and the revised position of Y , and this process is repeated until X and Y line up in both directions and A , X , Y and B are all in the same straight line. The survey line can then be chained and this will probably involve 'stepping' the chain due to the sloping nature of the ground.

Rivers. Fig. 6 illustrates a method of measuring a survey line which crosses a river.

It is necessary to extend the survey line ABC across the river on the line DEF . A line GBH is set out on the nearside bank of the river, from which the line HE can be set out at right angles to bridge the river and intersect the extended survey line at E . The line HB is then produced to

point G , whereby GH and BH are of equal length. A further right-angle is established at G with the offset intersecting the survey line at A .

The two triangles that have been formed (AGB and BHE) are similar and so the lengths AB and BE will be the same. The length of the survey line crossing the river has thus been determined.

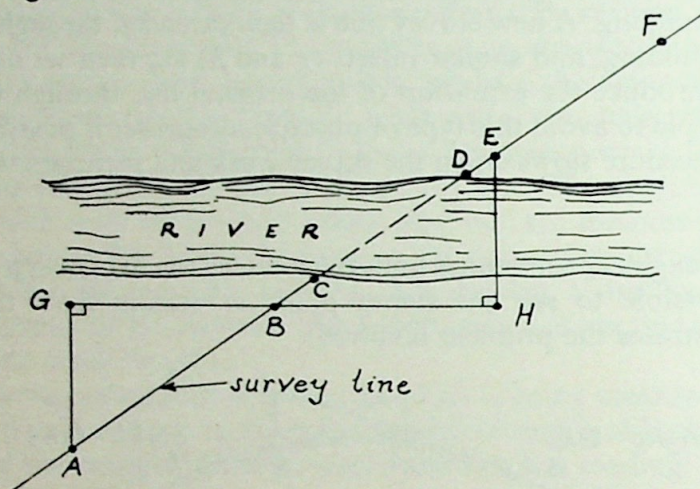


FIG. 6. Chaining across a river.

Field Book Entries. All measurements are recorded in a field book in the manner illustrated in Fig. 2. Each page of the field book normally has a fairly narrow column printed in red lines down the centre of the page. These lines represent the survey line and distances along it are entered in the column with offsets and ties shown on each side, working from the bottom of the page upwards. The dimension at each station or survey point is usually ringed to give emphasis.

The first entries in the field book cover the name of the site, date of survey and a sketch of the survey lines. The measurements are then suitably recorded under a heading giving the number of the survey line.

Plotting the Survey

The first step is to decide the scale to which the survey is to be plotted. A commonly used scale for housing estate work is $\frac{1}{80}$ (40·66 ft to 1 in.), although some engineers prefer to use multiples of the $\frac{1}{8}$ in. scale, such as $\frac{1}{32}$ in. to 1 ft or $\frac{1}{64}$ in. to 1 ft. When dealing with sites covering smaller areas which may be intensively developed, a larger scale such as $\frac{1}{16}$ in. to 1 ft may be more appropriate.

The main survey lines are then plotted using compasses, with lengthening bars where necessary, or even trammels or beam compasses, set to produce arcs of a radius equal to the distances between stations. It is

usual to plot the main base lines first, followed by triangular survey lines and lastly the diagonal check lines.

If all the survey lines check satisfactorily, then the engineer or assistant can proceed with the plotting of the boundaries and other features of the site from offset and tie measurements. Where the survey lines do not check, it will be necessary to take further measurements on the site.

The survey plan should have a proper title and the scale and north point incorporated on it. All adjoining roads and buildings should be suitably labelled for identification purposes. The north point is normally calculated from the bearing of the main base line which has been established on the site, often using a prismatic compass. Another alternative is to orientate one of the boundaries with its bearings on the Ordnance Survey map.

Fig. 7 illustrates a number of symbols which are in common use on land surveying plans.

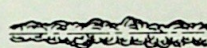
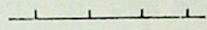
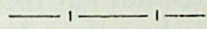
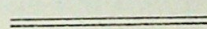
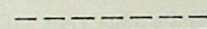
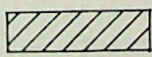
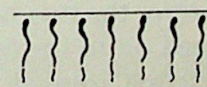
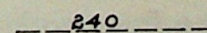
	<i>hedge</i>
	<i>post and boarded fence</i>
	<i>post and wire fence</i>
	<i>unspecified fence</i>
	<i>wall</i>
	<i>road</i>
	<i>building</i>
	<i>bank</i>
	<i>tree</i>
	<i>gate</i>
	<i>contour line</i>

FIG. 7. Symbols for land surveying plans.

Use of Theodolite

When surveying large areas, it is generally necessary to measure the angles between the main enclosing survey lines with a theodolite. Theodolites are also used extensively for setting out horizontal curves on roads, road intersections and in tunnel work.

Basically, the theodolite consists of a telescope which can be rotated in both horizontal and vertical planes, and when it can pass through a full circle in a vertical plane it is termed a *transit theodolite*. Two graduated circular scales are also attached to the instrument, one in a vertical and the other in a horizontal plane, so that the instrument can be used to measure angles of inclination and horizontal angles.

The theodolite telescope contains an object glass, an eyepiece and a diaphragm containing the cross hairs. The cross hairs were formerly made of spider's web but are now usually formed by etching fine lines upon glass. Internal focussing enables the cross hairs to be brought sharply into focus by a small movement of the eyepiece. The line of sight, or line of collimation of the instrument, is the projection of the line joining the optical centre of the telescope and the intersection of the horizontal and vertical cross wires. The telescope is supported by a frame which in its turn rests upon a horizontal flat rotating plate on a vertical axis, the whole instrument mounted on three levelling screws, a centring head and tripod.

The angles are read on both sides of the scales by means of verniers or optical micrometers. The actual divisions on the scales vary with the size and type of instrument.

To measure an angle in the field the instrument has first to be set up accurately over the station, usually a nail in the top of a wooden peg, with the aid of a plumb-bob and movement of all three tripod legs in the same direction and for the same distance. This task is simplified where an optical plummet is fitted. Next the instrument is levelled up using the three levelling screws and observing the bubbles in the bubble tubes.

The horizontal scale is now set to read zero, the two horizontal plates clamped together and the telescope focussed on to the first station. The plates are then unclamped and the telescope rotated in a clockwise direction to the second station, when the plates are reclamped and the angle read on both sides of the scale. One reading will need a deduction of 180° to arrive at the correct angle.

Traverse Surveys

The term 'traverse' is used to describe a framework of survey lines around the boundaries of the area to be surveyed, with the angles

between the survey lines measured with a theodolite. Offsets are measured from these main survey lines and it is usual for the traverse to be closed, by chaining back to the starting point. This permits of a ready check on the accuracy of the lengths and angles.

The best procedure is normally to measure the included angles between the survey lines. The sum of the interior angles of the traverse must equal $90(2n-4)$ degrees, where n is the number of survey lines. If a small error occurs, it will be sufficiently accurate to divide the error equally over all the angles. Thus for an 8-sided traverse the sum of the interior angles must be $90(2 \times 8-4) = 90 \times 12 = 1080^\circ$. If the sum of the measured interior angles totalled $1079^\circ 11' 20''$, the total error would be $48' 40''$ and the correction needed to each angle would be $6' 05''$.

Once the angles have been corrected, the positions of the stations can be determined by calculating their co-ordinates (latitudes and departures) and the survey lines can then be plotted. Finally the offsets and ties to the survey lines will be measured and the boundaries and other features plotted on to the plan.

For further information on land surveying readers are referred to the books listed in references 1 to 5 at the end of this chapter.

LEVELLING

The majority of municipal engineering works entail taking levels both prior to their design and during the execution of the constructional work. The greatest possible accuracy must be achieved in all levelling operations.

Use of Bench Marks

Most levelling starts from an Ordnance bench mark, which constitutes a point of known level, being the height in feet above high water level at Newlyn, Cornwall, so that all levels taken by the municipal engineer are in the same relationship. The positions and values of Ordnance bench marks are obtained from 1/2500 and 1/1250 Ordnance sheets or plans. They are usually cut into the walls of substantial buildings, bridge abutments, etc. about $2\frac{1}{2}$ ft above ground level, in the form of a broad arrow with a horizontal line above it, thus $\overline{\rightarrow}$. The bottom of the levelling staff is held at the same level as the centre of the horizontal cut above the broad arrow, often using a 6-in. rule for this purpose.

When the site is a great distance from the nearest Ordnance bench mark, and only relative levels are required, it may be considered sufficient to give an assumed level to some fixed point, such as the top of

a stone sill, brick wall or road kerb. The point should be suitably marked with a cut or white paint and it is often referred to as a *temporary bench mark* (T.B.M.). The value given to this point should be sufficiently high to prevent any negative values arising—100·00 is a value which is commonly adopted.

Instruments

The most commonly used types of level are the dumpy level and the precise level, although a simpler form of level known as the Cowley level is sometimes used on small building sites. Most engineers prefer to use the precise type level because of the higher standards of accuracy obtainable.

A diagrammatic sketch of a dumpy level is shown in Fig. 8 and a precise level in Fig. 9.

With both types of instrument the level is attached to the head of a wooden tripod which enables the level to be positioned at eye level. The

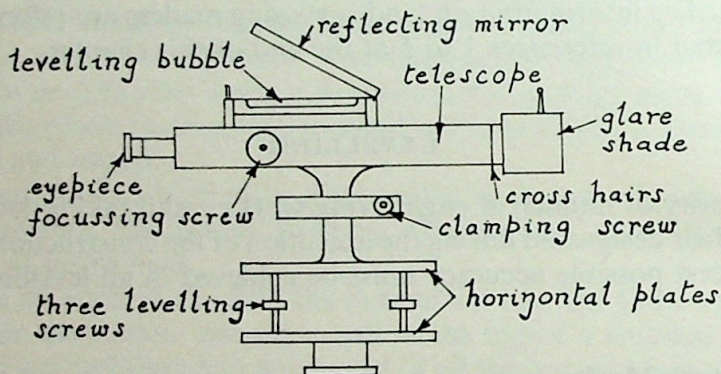


FIG. 8. Dumpy level.

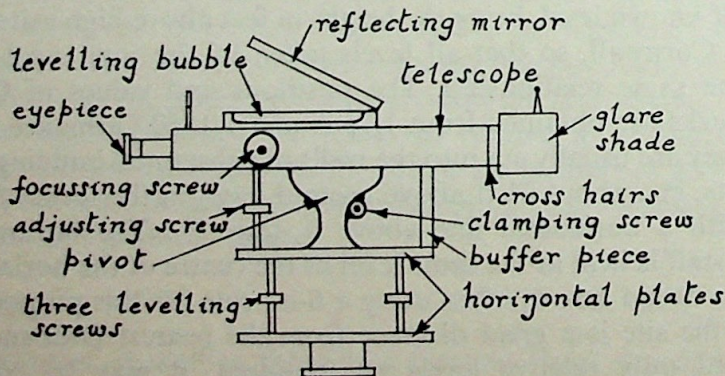


FIG. 9. Precise level.

setting up or primary levelling of the instrument is performed by forcing the tripod legs firmly into the ground, where practicable, and then bringing the bubbles to the centres of the bubble tubes by means of the levelling screws situated between the two horizontal plates.

A telescope is fitted above the levelling plates with an extendable eyepiece at one end, operated by a focussing screw, and with an object glass and sun shade at the other end. A diaphragm of cross hairs, usually etched or printed on the glass, is also contained in the telescope, and the intersection of these lines and the centre of the eyepiece extended produces the line of collimation. This is a level line from which the readings are taken.

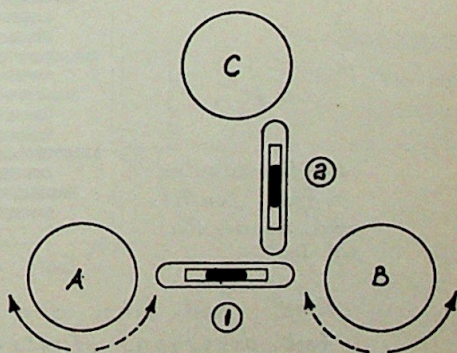
In the precise level the telescope is pivoted centrally, with a mill-headed elevating screw at the eyepiece end and a buffer piece at the other end. Adjustments are made with the elevating screw between readings to keep the bubble in a central position. Yet another type of level has a ball and socket arrangement instead of the pivoted bearing.

Setting up a Level

The plates on the instrument are first set roughly parallel and level. Then the telescope is swung over two opposite levelling screws which are adjusted until the bubble is central in its tube. The telescope is rotated through 90° , so that the telescope is over the third levelling screw, and the bubble is brought to a central position using the third levelling screw alone. This process is repeated until the bubble remains central in both positions, when the instrument is truly level. This procedure is illustrated in Fig. 10.

Where a level is out of adjustment, it will be impossible to bring the bubble central for both positions of the telescope. In these circumstances, it is best to equalise the error over the two positions and to try and keep backsights and foresights of approximately equal length.

*SECOND POSITION:
Bubble turned through 90°
and brought to centre of run
by screw C*



*FIRST POSITION:
Bubble brought to centre of run
by turning screws A and B
(bubble moves in direction of screw A)*

FIG. 10. Setting up a level.

When using a dumpy level, the levelling screws must remain untouched between each change of position of the instrument. The focussing screw will be turned when the length of sight is changed appreciably. With the precise level, on the other hand, the levelling screws must remain untouched but the elevating screw can be adjusted as often as necessary to keep the bubble on the telescope in its central position.

It is desirable that the legs of the tripod should form an angle of about 60° with the ground to give maximum stability and the feet of the tripod should be firmly driven into the ground, wherever possible, to prevent any likelihood of movement once the instrument has been levelled.

Levelling Staff

The commonest form of levelling staff is that known as the Sopwith staff and part of one is illustrated in Fig. 11. The staff is usually made in 3 separate lengths of mahogany, and these slide into one another to give a length of about 5 ft when compacted and up to 14 ft when fully extended. Longer lengths are produced but they become almost unmanageable in very windy conditions. Some engineers prefer to use single section staffs to avoid any errors resulting from defective joints in sliding or telescopic staffs.

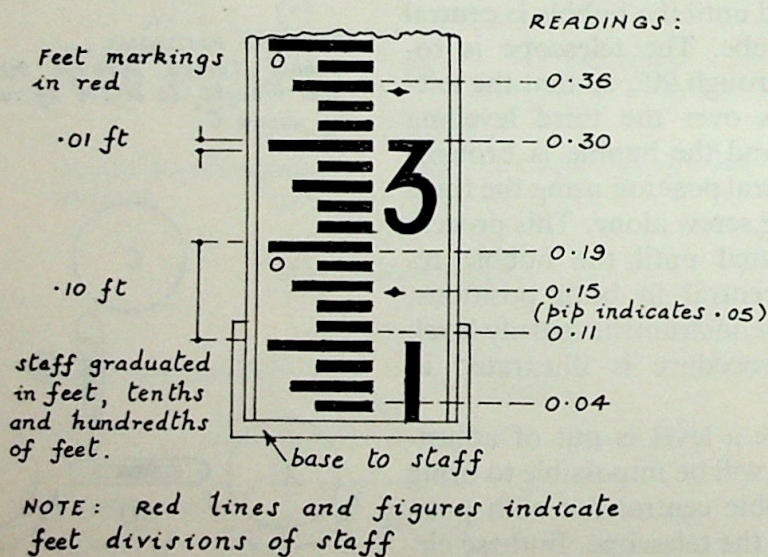


FIG. 11. Sopwith staff.

The person operating the level can readily see whether the staff is vertical in a transverse direction by lining it up with the two vertical stadia hairs in the instrument. Verticality in the opposite direction is

best checked by the person holding the staff swinging it slowly backwards and forwards, when the smallest reading will indicate the vertical position.

Most levels invert the objects seen through them and, for this reason, some levelling staffs have their markings inverted so that they will be in correct relationship when viewed through the instrument. In practice engineers soon become accustomed to reading inverted staff markings and they present no real problem. The figures on the staff usually represent feet, and tenths and hundredths of a foot and are normally in red with the lines or divisions in black.

Using a Level

The instrument should always be located so that as many levels as possible can be taken from a single set-up. Before any readings can be taken it is necessary to adjust the eyepiece to eliminate parallax and to suit the eyesight of the user. The focussing screw will also be turned whenever the length of sight is varied appreciably in order to obtain a clear view of the staff.

When positioning the instrument it is also desirable to equalise the lengths of backsights and foresights, as far as possible. It will be appreciated that approximately 14 ft of staff is available in a downhill direction but only 4 or 5 ft (the height of the instrument) in an uphill direction, and this has an important influence on the positioning of the instrument. When the staff is held very close to the level, it may be necessary to move some object, such as a rule or piece of paper, up and down the staff to help determine the reading.

The first reading of a series of levels, often taken on an Ordnance bench mark, is termed a *backsight*. Any further readings, except the last, taken from the same position are termed *intermediates*. The last reading is called a *foresight* and is taken on some permanent feature, such as the top of a wall or kerb, which has been suitably marked.

The instrument is then set up in a new location to continue with a further section of levels. The first reading from the new position of the level will be on to a fixed point, whose level has been established already. If any reading is greater than the previous one then the ground level is falling and the reduced level will be less, and this is well illustrated in the example that follows. When all the required levels have been taken, it is good policy to check back to the bench mark from which the levelling was commenced, using as few change points as possible and limiting the readings to backsights and foresights, in order to check the accuracy of the work, and these are known as *flying levels*. The following sketch

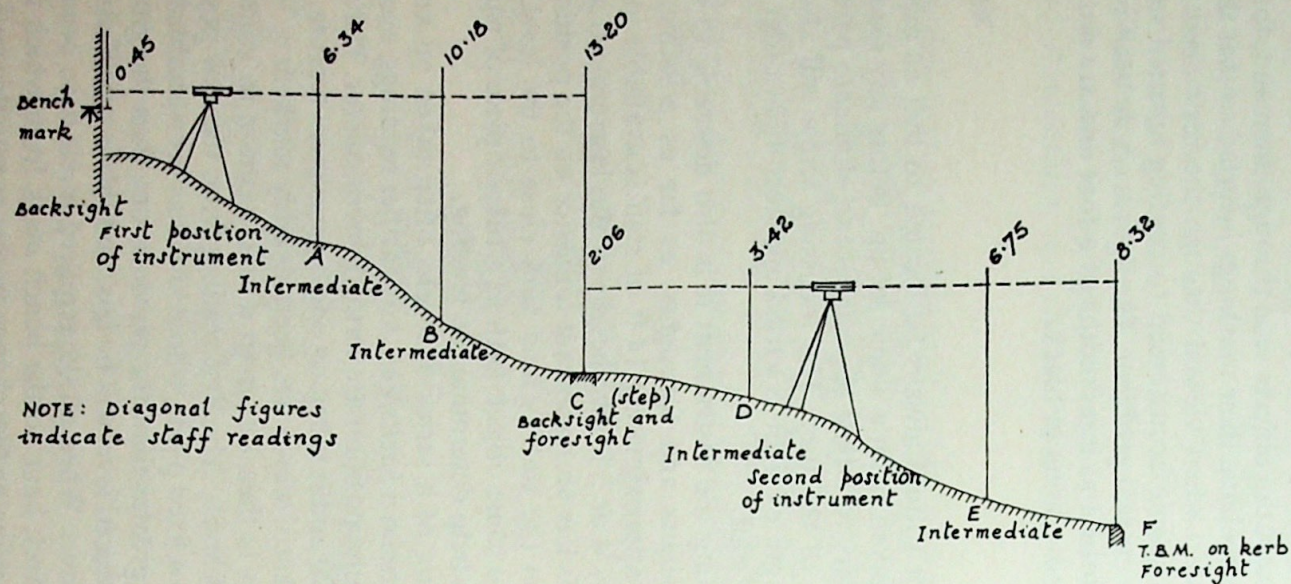


FIG. 12. Levelling.

illustrates some levelling work carried out from two positions of the instrument.

Booking Levels

There are two principal methods of booking levels: (1) rise and fall, (2) collimation. The rise and fall level book ruling contains one column for entering the amount of rise from one reading to the next, and another column in which to enter falls. Hence the amount of rise and fall has to be calculated for each level point and it entails more labour in determining reduced levels than the collimation method, but it has the great advantage of permitting every level to be checked. Table 1 shows the levels from Fig. 12 entered on the rise and fall method.

In the collimation method, each reduced level is found by deducting the reading at that point from the height of collimation level of the instrument. This method has the advantage of speed in reducing levels and is popular with engineers. In practice, it is usually possible to calculate the reduced level for one point whilst the chainman is moving to the next staff position. The levels from Fig. 12 are shown entered on the collimation method in Table 2.

TABLE 1. RISE AND FALL METHOD OF BOOKING LEVELS

<i>Back sight</i>	<i>Interm.</i>	<i>Fore sight</i>	<i>Rise</i>	<i>Fall</i>	<i>Reduced level</i>	<i>Distance</i>	<i>Remarks</i>
0.45					252.40		O.B.M.
	6.34			5.89	246.51		A
	10.18			3.84	242.67		B
2.06		13.20	3.02		239.65		C(T.B.M. on step)
	3.42		1.36		238.29		D
	6.75		3.33		234.96		E
		8.32	1.57		233.39		F(T.B.M. on kerb)

TABLE 2. COLLIMATION METHOD OF BOOKING LEVELS

<i>Back sight</i>	<i>Interm.</i>	<i>Fore sight</i>	<i>Height of collimation</i>	<i>Reduced level</i>	<i>Distance</i>	<i>Remarks</i>
0.45			252.85	252.40		O.B.M.
	6.34			246.51		A
	10.18			242.67		B
2.06		13.20	241.71	239.65		C(T.B.M. on step)
	3.42			238.29		D
	6.75			234.96		E
		8.32		233.39		F(T.B.M. on kerb)

In the collimation method the backsight reading of 0.45 is added to the Ordnance bench mark value of 252.40 to give the height of collimation of the instrument of 252.85. Intermediate reduced levels are then found by deducting the reading at each point from the height of collimation figure.

At point C, taken on a step as a suitable position for a change point or temporary bench mark, two readings are taken at the same point and so they are both entered on the same line in the level book. The first reading is entered as a foresight and enables the reduced level to be calculated, whilst the second reading from a new position of the instrument is a backsight and added to the reduced level gives the new height of collimation.

Plotting Levels

When the levels have been reduced in the level book, they are usually entered on a site plan of the site, with their exact location indicated by a cross, e.g. +126.43. When surveying a housing site, a grid of levels will normally be taken at 25 or 50 ft intervals, the actual spacing depending upon the slope and general surface configuration. Contour lines, often at 1 ft or 2 ft vertical intervals, will be interpolated between the ground levels or *spot levels*, as they are often called.

When planning roads and sewers, it is sometimes the practice to set out the lines of the roads and sewers on the site and to take levels along the route. The more usual practice is to determine the probable ground levels along the lines of the roads and sewers from the spot levels and contour lines on the site plan. Longitudinal sections are prepared along the sewer runs and along the centre lines of the roads. In addition to ground levels, the finished road levels and sewer invert levels will also be given. Longitudinal sections are almost invariably plotted to an exaggerated scale, such as a horizontal scale of 1/500 and vertical scale of 10 ft to 1 in., or 1/2500 horizontally and 40 or 50 ft to 1 in. vertically—a ratio of about 1 to 4. This method of plotting helps to emphasise the differences in levels between different points.

TACHEOMETRY

Tacheometry permits the measurement of distances by taking two readings with a tacheometer at one end of the line, from a levelling staff held at the other end of the line to be measured. An ordinary level can be used for this purpose provided it has 3 horizontal stadia hairs or lines.

The difference in the values of the readings produced by the top and bottom stadia lines multiplied by the appropriate constant for the particular instrument, will give the distance from the instrument to the required point in feet.

Fig. 13 illustrates a level being used in this way.

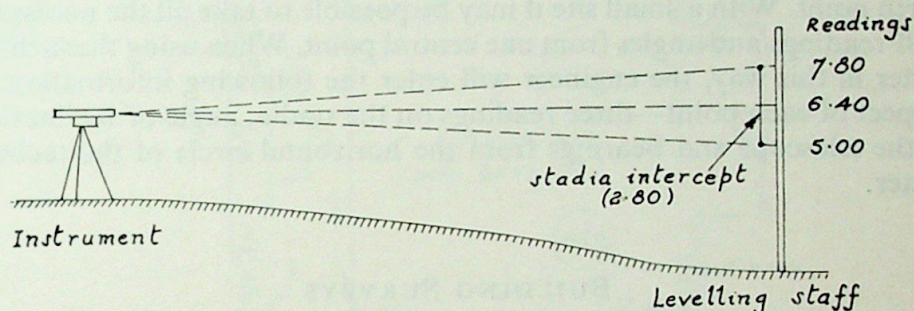


FIG. 13. Measuring by tacheometer.

Top stadia line reading	=	7.80
Bottom stadia line reading	=	5.00
Difference in readings (stadia intercept)		<u>2.80</u>

$$\text{Distance} = 2.80 \times 100 \text{ (constant for instrument)} = 280 \text{ ft.}$$

It will at once be seen that this form of measurement can be invaluable to the municipal engineer, as for instance when he wants to measure distances over broken or marshy ground, or over a canal or river.

Where the measurements are required over sloping ground, two distances have to be calculated—the horizontal and vertical distances between the tacheometer and the levelling staff or stadia rod. In these circumstances a tacheometer proper is needed as the angle of inclination of the telescope will be required in addition to the two stadia readings. The tacheometer proper is a type of theodolite equipped with a specially marked diaphragm, and it possesses greater magnifying power than the normal theodolite.

Taking the angle of inclination as A and the constant for the instrument as 100, then the distances can be calculated as follows:

- (1) Horizontal distance = stadia intercept $\times 100 \cos^2 A$
- (2) Vertical distance = stadia intercept $\times 100 \sin A \cos A$.

The vertical distance so calculated will represent the height from the telescope of the instrument to the centre stadia intercept on the staff.

It will, therefore, be necessary to add the height of the tacheometer telescope above ground and to deduct the reading of the centre stadia line.

It is also possible to carry out surveys of land with a tacheometer and so eliminate all chaining. The horizontal angles between the various points will be recorded and, where necessary, they can be related to the north point. With a small site it may be possible to take all the necessary staff readings and angles from one central point. When using the tacheometer in this way, the engineer will enter the following information in respect of each point—three readings on the stadia, angle of inclination of the telescope and bearings from the horizontal circle of the tacheometer.

BUILDING SURVEYS

The municipal engineer is sometimes called upon to carry out surveys of existing buildings for which up-to-date plans are not available. The author received his training in municipal engineering during the war years, when he carried out building surveys of all the principal buildings in the town where he was articled—schools, halls, hotels, etc., capable of being used as emergency feeding centres, mortuaries and for other war-time uses.

Buildings are normally surveyed with a linen tape and a wood or steel rule. The overall dimensions of each room are recorded on an outline sketch of the building drawn in a field book or on sheets of squared paper. The diagonals across the room will also need to be measured if the rooms are not square.

Measurements of window and door openings and of the lengths of walling between them will be duly recorded. Chimney breasts, piers and other projections will be shown with their dimensions and the thicknesses of all walls and partitions. The heights of rooms are usually recorded in circles.

When measuring elevations, it is usually sufficient to give the number of brick courses, normally 3 in. deep, to arrive at the heights of gables, chimney stacks, etc. In addition to the heights of windows, it will also be necessary to take the sill height from ground or floor level, in order to position them on the elevations.

The sketches prepared in connection with building surveys are usually freehand but they need to be extremely neat and easily interpreted. Student engineers and surveyors frequently make the mistake of drawing very small sketches which soon become badly congested with dimensions

and descriptive data. It is much better to keep all sketches on the large side as they will then be so much easier to follow.

The field book entries covering the building survey of part of a house are shown in Fig. 14.

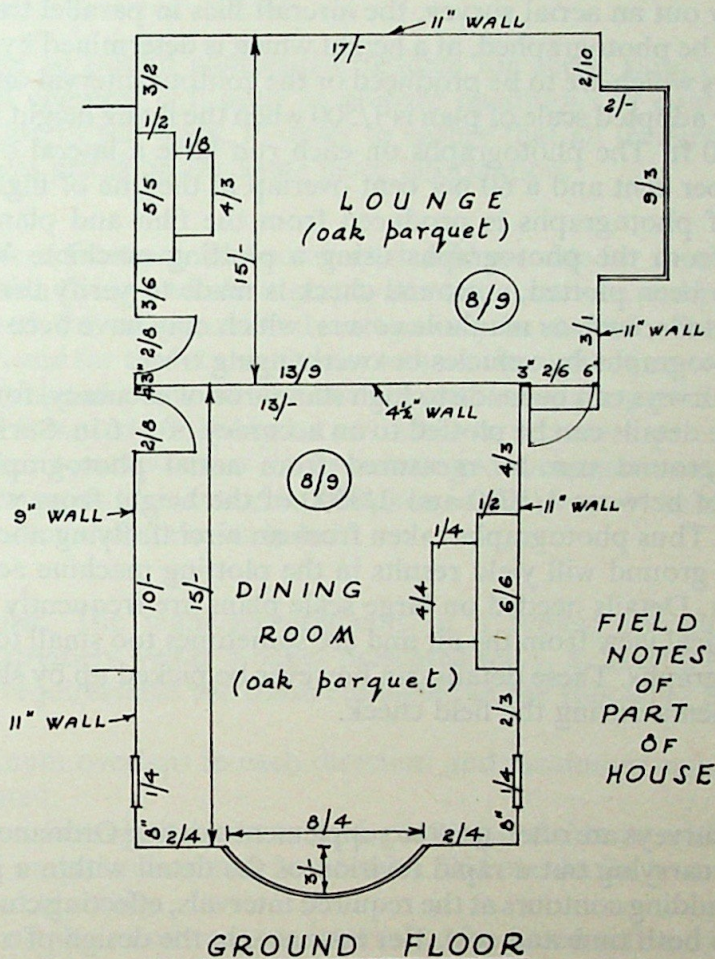


FIG. 14. Building survey.

AERIAL SURVEYS

Various local authorities have had aerial surveys of parts of their areas carried out during recent years, preparatory to the preparation of schemes for new roads, road improvements, housing estates, etc. This process has been accelerated due to staff shortages in municipal engineers'

offices and the fact that aerial surveys have often proved to be less costly than traditional ground surveys.

Methods and Standards of Accuracy

To carry out an aerial survey, the aircraft flies in parallel tracks over the area to be photographed, at a height which is determined by the scale of the plans which are to be produced or the contour interval on them. A commonly adopted scale of plan is 1/500 when the flying height is usually about 1300 ft. The photographs on each run have a lateral overlap of about 30 per cent and a 60 per cent overlap in the line of flight.

A set of photographs is produced from the film and plans can be prepared from the photographs using a plotting machine. When the plans have been plotted, a ground check is made to verify them and to pick up details, such as manhole covers, which may have been obscured in the photographs by vehicles or overhanging trees.

Aerial surveys can be made to high standards of accuracy, for instance 1/500 scale details can be plotted to an accuracy of ± 6 in. Surface levels on clear ground can be measured from aerial photographs to an accuracy of between 1/5000 and 1/8000 of the height from which they are taken. Thus photographs taken from an aircraft flying about a mile above the ground will yield results in the plotting machine accurate to within 1 ft. Details needed on large scale plans are frequently obscured in the vertical view from the air and are sometimes too small to show on the photographs. These details can however be picked up by short offset measurements during the field check.

Uses

Aerial surveys are often used to supplement existing Ordnance maps or plans, by carrying out a rapid revision of the detail within a particular area and adding contours at the required intervals, effecting considerable savings in both time and cost. For instance, in the design of a sewerage scheme for a group of villages, the 1/2500 or 6 in. to 1 mile Ordnance plans or maps of the area will often be sufficient, if they are revised and contours added at 5-ft intervals. The physical characteristics and general features of the ground can readily be determined from these contoured plans or maps and the most satisfactory and economical lines for the sewers can be established.

It is sometimes possible to survey quite small sites from the air more economically than by normal ground methods, where there is considerable detail to be picked up and access is difficult. The air photographs alone can often be of considerable use when produced as photo-maps or

mosaics. They are much cheaper than the usual map or plan and provide very useful information for those who are more concerned with surface detail than accuracy of scale.

Contracts

In order to obtain competitive tenders for aerial survey work, the municipal engineer will need to prepare conditions of contract and a specification of the work, in order to ensure that all tenderers are preparing their prices on the same basic information.

Conditions of Contract. The contract should provide for specific periods within which flying and photography are to commence and plans are to be prepared. Provision could advantageously be made for the pricing of variations and for the local authority to have the right of reproduction of photographs and plans. Where the contract covers a period exceeding two years it would probably be advisable to include a price variation clause. The normal contract clauses relating to such matters as insurance cover, arbitration and action to be taken in the event of bankruptcy of the contractor should be included.

Specification. The main requirements of a typical specification are covered extremely well in a paper presented by A. S. Martin (6). Briefly the main requirements are those contained in the following list:

- (1) Minimum overlaps in each direction and maximum camera tilt to be stated.
- (2) Use of first-class cameras and plotting machines, with plotting based on ground control points with field checks for horizontal and vertical accuracy.
- (3) Scale of plans and contour interval to be stated (often 1/500 plans with contours at 1-ft vertical interval).
- (4) Standards of horizontal and vertical accuracy to be given.
- (5) Extent of photography shown on a key plan.
- (6) Set of photographs, index showing their location and hand stereoscope to be supplied in addition to plans.
- (7) Width of plans covering highway improvement work (probably 60 to 100 ft on each side of centre line of existing carriageway).
- (8) Plans to be supplied on Permatrace with all road names and classification numbers, house numbers and north point shown.
- (9) List of ground features to be shown, e.g. street lighting columns,

ventilating columns, traffic signs and trees (trunks to be shown where they exceed 6 in. in diameter, measured 3 ft above ground level).

SETTING OUT MUNICIPAL ENGINEERING WORK

The municipal engineer must be well versed in setting out work as the bulk of municipal engineering work has to be constructed to high standards of accuracy. With contract work the municipal engineer is usually responsible for checking the setting out work carried out by the contractor, but with direct-labour work he is often required to perform all setting out.

Roads

Road lines are usually set out from the dimensions entered on setting out drawings, where road lengths, radii and angles of intersections are shown. Some engineers set out roads on their centre-lines but the more usual practice is to set out road lines at a fixed distance back from the face of the kerbs, such as 2 or 3 ft. This latter procedure has the great advantage that the pegs are less likely to be disturbed when earth-moving operations take place. The pegs are usually about 2 in. $\times$ 2 in. in section and some 30 in. in length, and it is advisable to surround them with concrete and to paint the tops of the pegs a distinctive colour, such as red. The pegs are often spaced at 100-ft intervals on straight lengths and at 20-ft intervals on curves.

Level pegs, at much the same intervals, are established in a similar manner and they will also be painted a distinctive colour, such as blue. Level pegs are usually provided on vertical curves at about 20-ft intervals and level points between the 20-ft levels are normally eyed in with line and steel pins, set alongside the face line of the kerbs at about 6 to 7-ft intervals, to eliminate kinks in the kerb lines.

Angles are almost invariably set out with a theodolite and the base lines will be located by measurements taken with a steel tape to fixed points on the site, the necessary dimensions being read or scaled from the drawings. Horizontal curves are best set out from a tangent point using a theodolite, although in the absence of an instrument the offset method can be used for this purpose.

The following example illustrates the method of setting out a curve with a theodolite.

The theodolite is set up over the tangent point *B* and sighted back along the setting out line to *A*. The instrument is then transited to sight

along the line to C . The first point on the curve, peg 1, is now positioned by turning the telescope through the tangential angle ($\angle CBD$), which is equal to half the angle at the centre of the circle subtended by the chord BD . The chords are usually taken in lengths of 20 ft. The second peg will be positioned by setting the telescope at twice the tangential angle from B and measuring a further 20 ft from D to E .

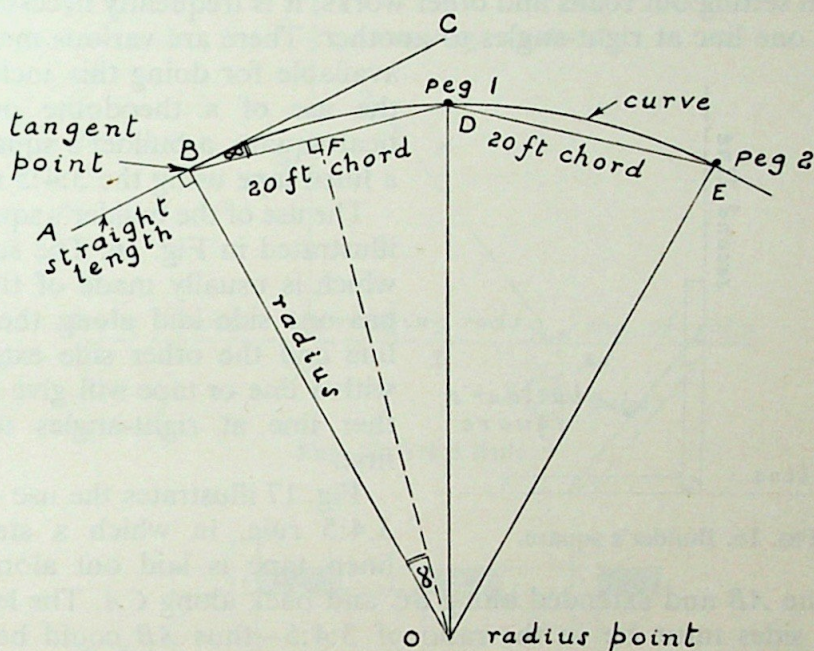


FIG. 15. Setting out a curve.

$$\text{The tangential angle in minutes} = \frac{1719 \times \text{chord}}{\text{radius}}.$$

This process is continued until all the points along the line of the curve, at 20-ft intervals, have been established.

In the offset method, the engineer measures 20 ft along the line BC and then sets off a right-angled offset towards D equal to

$$\frac{\text{chord}^2}{2 \times \text{radius}}.$$

Peg 2 is established by measuring a further 20 ft along line BD produced and another offset is then set out towards E equivalent to

$$\frac{\text{chord}^2}{\text{radius}},$$

and this process continues until all the points on the curve have been fixed.

Right-Angles

When setting out roads and other works, it is frequently necessary to set out one line at right-angles to another. There are various methods available for doing this including the use of a theodolite or optical square, a builder's square or a linen tape using the 3:4:5 rule.

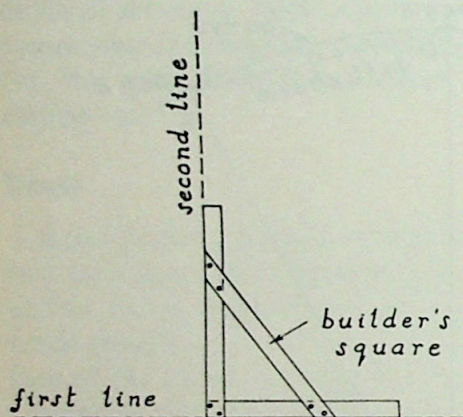


FIG. 16. Builder's square.

The use of the builder's square is illustrated in Fig. 16. The square, which is usually made of timber, has one side laid along the base line and the other side extended with a line or tape will give a further line at right-angles to the first.

Fig. 17 illustrates the use of the 3:4:5 rule, in which a steel or linen tape is laid out along the base line AB and extended along BC and back along CA . The lengths of the sides must be in the ratio of 3:4:5—thus AB could be 9 ft, BC : 12 ft and CA : 15 ft.

The usual procedure is for each of three persons to hold a ranging rod at each of the three points, and to ensure that the correct readings are showing on the tape at these points (i.e. 9 ft, 21 ft and 36 ft respectively). When these conditions operate the $\angle ABC$ is a right-angle and BC can be extended to give the line required.

Sewers

To ensure that sewers are laid to the correct levels and gradients, sight rails consisting of horizontal boards, often painted alternately black and white and supported by posts, are set up at all manholes. The sight rails are positioned with the aid of a dumpy or precise level at a convenient height for sighting purposes in feet above the invert level of the sewer. Intermediate invert levels of pipes are determined with boning rods sighted between the sight rails, as shown in Fig. 18.

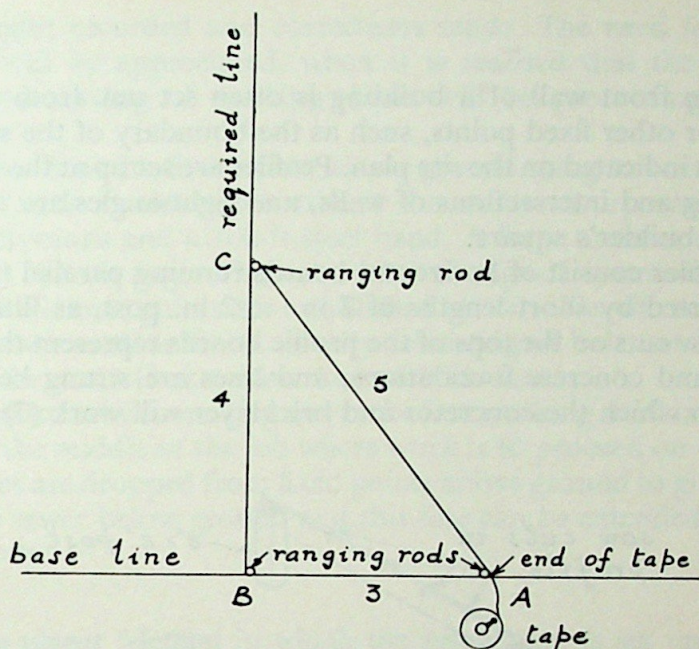


FIG. 17. 3:4:5 Rule.

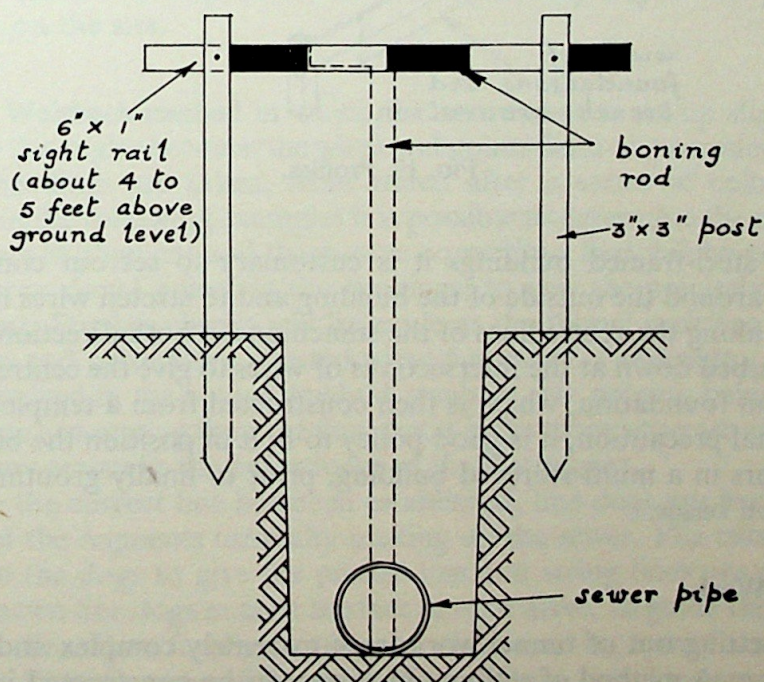


FIG. 18. Sight rails.

Buildings

The main front wall of a building is often set out from adjoining buildings or other fixed points, such as the boundary of the site, to the dimensions indicated on the site plan. Profiles are set up at the corners of the building and intersections of walls, and right-angles are usually set out with a builder's square.

The profiles consist of horizontal boards running parallel to the wall and supported by short lengths of 2 in. $\times$ 2 in. post, as illustrated in Fig. 19. Saw cuts on the tops of the profile boards represent the edges of the walls and concrete foundations, and lines are strung between the saw cuts to which the concreter and bricklayer will work (7).

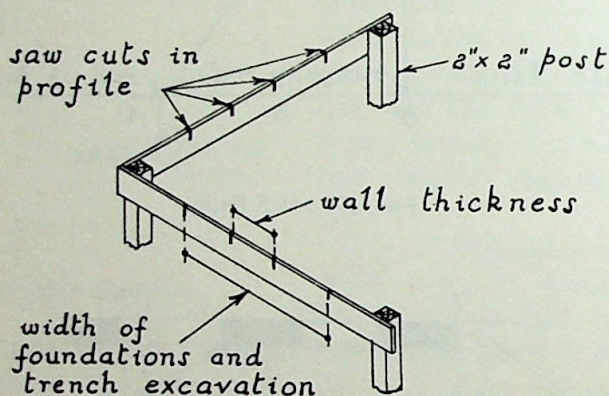


FIG. 19. Profiles.

With steel-framed buildings it is customary to set out continuous profiles around the outside of the building and to stretch wires from the profiles along the centre lines of the stanchions in both directions. Lines are plumbed down at the intersections of wires to give the centre of each stanchion foundation, which is then constructed from a templet. As an additional precaution, it is good policy to bolt in position the beams on two floors in a multi-storeyed building, prior to finally grouting in the stanchion bases.

Tunnel Work

The setting out of tunnel work is an extremely complex and precise operation. A method of setting out sewers to be constructed in tunnel is now described, followed by an example showing the actual measure-

ments, angles recorded and corrections made. The need for absolute accuracy will be appreciated, when it is realised that the driving of tunnels and sinking of working shafts will be proceeding simultaneously.

The sewer lines are first set out above ground using traverse methods, preferably with a micrometer transit theodolite incorporating a scale with 10" divisions and a 100-ft steel band. A large number of readings are needed of each angle where there is a change of direction of the line of sewer. Reference points are established on two sides of each manhole beyond the excavation limits, usually consisting of bolts set in concrete on which the exact lines are marked with file cuts.

To commence the tunnelling work, the first working shaft is excavated, usually in the middle of the job where work is to proceed on two tunnel faces. Wires are dropped from fixed points above ground to give the base line of the sewer below ground and this line can be extended by one of two methods.

(1) **The Co-planer Method** in which the instrument is set up in a pilot heading in perfect alignment with the wires and the theodolite is then transited to produce the line. The main disadvantage of this method is the time taken to set up the instrument which may impede the progress of work on the site.

(2) **The Weisbach method** in which the instrument is set up slightly off line and the angles between the wires and points fixed on provisional lines in the headings are taken, from which after a series of calculations (shown in the following example) it is possible to determine the extent of any errors in alignment and the minute corrections that will be necessary at the provisional points in the headings, to give the precisely correct alignment. Further checks will be made as the tunnel is driven in each direction and corrections effected when necessary. The lengthy calculations involved in the second method result in this process being rather more time consuming than the first, but it is the more accurate and overcomes any errors in the adjustment of the instrument.

When the correct line has been established, line dogs are fixed in the crown of the segments normally making up the sewer. File cuts will be made on the dogs to give the precise line and string lines are dropped from the two line dogs nearest the face in each drive, to guide the miners who use these lines to align a piece of white card on trammel sticks held horizontally at the axis of the tunnel face. All the line dogs are suitably referenced.

Checking a Sewer Line in Tunnel. The following example illustrates a method of checking the line, soon after the first working shaft has been sunk.

Measurements above ground

Ref. point to east wire	18·535
Ref. point to west wire	30·135
Wire interval	11·600
Bearing	270°00'00"

Banding below ground

		<i>Distance in feet</i>
Dog 36 downstream	×	50·00
Dog 12 downstream	×	28·17
Instrument position	×	18·65
East wire	×	11·60
West wire	×	26·08
Dog 1 upstream	×	39·68
Dog 21 upstream	×	29·40
Dog 35 upstream	×	

(Note: Dog numbers refer to number of rings in tunnel lining.) These measurements, together with the angles recorded and the various co-ordinates are shown in Figs. 20 and 21 and these are followed by the calculations relating to the angles, bearings and co-ordinates.

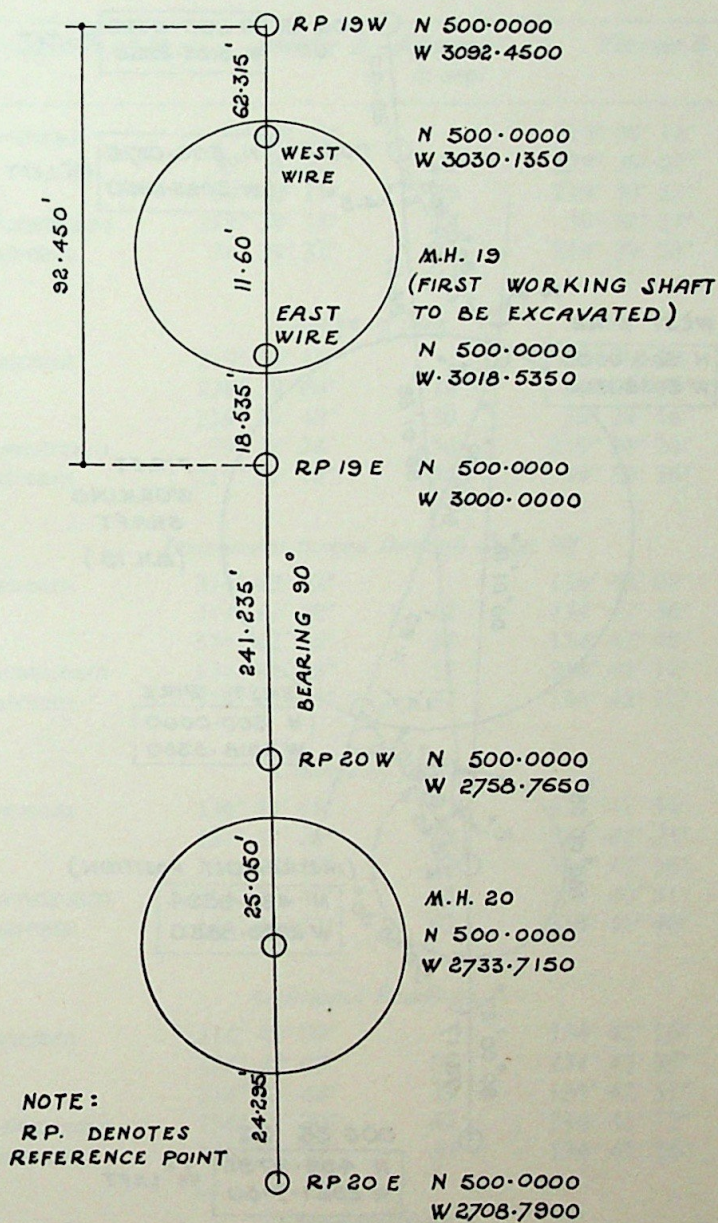


FIG. 20. Tunnel setting out—above ground.

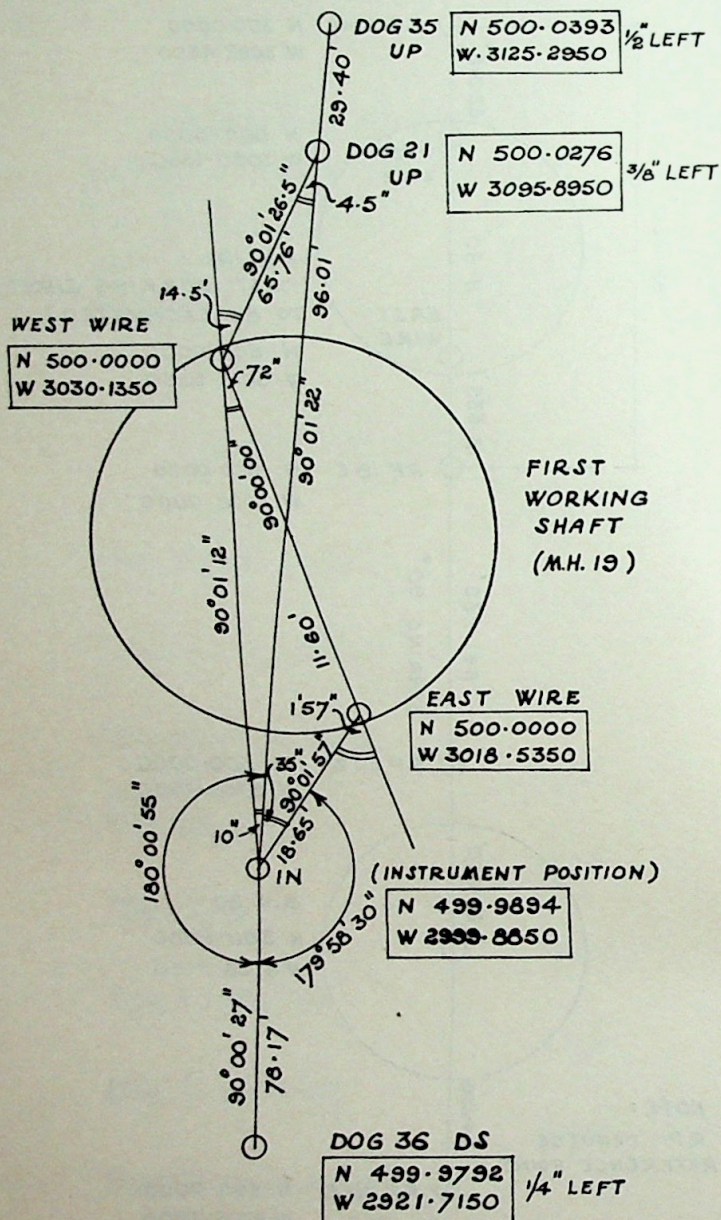


FIG. 21. Tunnel setting out—below ground.

ANGLES TAKEN FROM IN (INSTRUMENT POSITION)

<i>Point sighted on to</i>	<i>Vernier A</i>	<i>difference in secs</i>	<i>Vernier B</i>	<i>difference in secs</i>
Dog. 35 upstream	39° 39' 32"		219° 39' 14"	
West wire	39° 39' 22"	10	219° 39' 08"	06
East wire	39° 40' 11"	39	219° 39' 52"	38
Dog 36 downstream	219° 38' 35"	24	39° 38' 27"	35
Dog 35 upstream	39° 39' 32"	57	219° 39' 28"	61
<i>Change of face</i>				
Dog 35 upstream	219° 39' 18"		39° 39' 20"	
West wire	219° 39' 04"	14	39° 39' 13"	07
East wire	219° 39' 48"	30	39° 39' 56"	36
Dog 36 downstream	39° 38' 24"	36	219° 38' 24"	28
Dog 35 upstream	219° 39' 18"	54	39° 39' 26"	62
<i>Instrument turned through about 90°</i>				
Dog 35 upstream	314° 42' 02"		134° 42' 06"	
West wire	314° 41' 50"	12	134° 41' 56"	10
East wire	314° 42' 36"	34	134° 42' 40"	34
Dog 36 downstream	134° 41' 28"	52	314° 41' 12"	32
Dog 35 upstream	314° 42' 05"	37	134° 42' 12"	60
<i>Change of face</i>				
Dog 35 upstream	134° 41' 48"		314° 41' 34"	
West wire	134° 41' 38"	10	314° 41' 25"	09
East wire	134° 42' 27"	39	314° 42' 16"	42
Dog 36 downstream	314° 40' 45"	18	134° 40' 51"	35
Dog 35 upstream	134° 41' 52"	67	314° 41' 40"	49
<i>Additional Readings</i>				
Dog 35 upstream	314° 42' 09"		134° 42' 16"	
West wire	314° 42' 00"	09	134° 42' 08"	08
East wire	314° 42' 48"	39	134° 42' 51"	35
Dog 36 downstream	134° 41' 30"	42	314° 41' 17"	26
Dog 35 upstream	314° 52' 27"	57	134° 42' 24"	67
<i>Change of face</i>				
Dog 35 upstream	203° 27' 17"		23° 27' 17"	
West wire	203° 27' 03"	14	23° 27' 06"	11
East wire	203° 27' 51"	34	23° 27' 54"	37
Dog 36 downstream	23° 26' 18"	27	203° 26' 12"	18
Dog 35 upstream	203° 27' 13"	55	23° 27' 06"	54

CALCULATION OF AVERAGE ANGLES

<i>Dog 35 Up— East Wire</i>	<i>Dog 35 Up— West Wire</i>	<i>East Wire— Dog 36 Dn</i>	<i>Dog 36 Dn— Dog 35 Up</i>
39	10	42	57
38	06	26	67
30	14	27	55
36	07	18	54
34	12	24	57
34	10	35	61
39	10	36	54
42	09	28	62
39	09	52	37
35	08	32	60
34	14	18	67
37	11	35	49
12 $\overline{)437}$	12 $\overline{)120}$	12 $\overline{)373}$	12 $\overline{)680}$
36.420"	10.000"	31.083"	56.666"

Actual Values for angles

36.420
31.083
56.666
124.169"

124.169
120.000
3 $\overline{)4.169}$
1.389

Amended figures for angles

35.031 — (35")
29.694 — (30")
55.277 — (55")
120.002" (2')

Angle between Dog 35 upstream and West Wire taken 10 times.

First Reading—23° 35' 05"

Second Reading—23° 27' 38"

7' 27"

60

420

27

447

Average Reading = 44.7 secs.

Angles

West Wire — IN — Dog 21 Up.	0° 00' 10"	179° 58' 30"
West Wire — IN — East Wire	0° 00' 45"	180° 00' 55"
Dog 21 Up. — IN — East Wire	0° 00' 35"	<u>360° 00' 00"</u>
East Wire — IN — Dog 36 D.S.	179° 58' 30"	
Dog 36 D.S. — IN — Dog 21 Up.	180° 00' 55"	

Angle IN—West Wire—East Wire = 18.65×45

$$\begin{array}{r} 11.60 \\ 18.65 = 1.2706788 \\ 45 = 1.6532125 \\ \hline 2.9238913 \\ 11.60 = 1.0644580 \\ \hline 1.8594333 = 72.349'' \\ 45 \\ \hline 1' 57'' \end{array}$$

$\angle$ checked by Sine Rule— $\sin X = \sin 45 \times \frac{18.65}{11.60}$

$$\begin{array}{r} 11.60 \\ 18.65 = 1.2706788 \\ \sin 45 = 6.3387874 \\ \hline 7.6094662 \\ 11.60 = 1.0644580 \\ \hline \sin 6.5450082 = 72.4'' \end{array}$$

Wire bearing = $90^\circ 00' 00''$
 $01' 57''$

Bearing E.W.—IN. = $90^\circ 01' 57''$
 $00' 35''$

Bearing IN—Dog 21 Up. = $90^\circ 01' 22''$

Bearing IN—Dog 36 D.S. = $90^\circ 00' 27''$

CO-ORDINATES

$$IN \cos. 1' 57'' = \frac{\chi}{18.65} \quad \chi = \cos. 1' 57'' \times 18.65.$$

$$\begin{array}{r} 18.65 = 1.2706788 \\ \cos. 1' 57'' = 9.9999999 \\ \hline 11.2706787 = 16.85' \end{array}$$

$$\begin{array}{r} 18.65 = 1.2706788 \\ \sin 1' 57'' = 6.7537607 \\ \hline 8.0244395 = .0105789 \end{array}$$

$$\begin{array}{r} .9894211 = N 499.9894 \\ Dog 36 D.S. \sin 0' 27'' = 6.1169386 \quad N. 499.9894 \\ 78.170 = 1.8930401 \quad 0.0102 \\ \hline 8.0099787 \quad N. 499.9792 \end{array}$$

W.2999·8850

78·1700W.2921·7150*Dog 21 Up.* 18·6511·6030·25

$$30·25 \times 10'' = 4·5''$$

65·76

W.2999·8850

96·0100W.3095·8950

$$\text{Sin } 1' 22'' = 6·5993887 \quad \text{N.499·9894}$$

$$96·01 = 1·9823165 \quad \cdot 0382$$

$$8·5817052 \quad \text{N.500·0276}$$

$$= \cdot 038168$$

$$\text{Dog 35 Up. Sin. } 1' 22'' = 6·5993887$$

$$\text{N.499·9894}$$

$$125·41 = 2·0983322$$

$$\cdot 0499$$

$$8·6977209 = \cdot 049856 \quad \text{N.500·0393}$$

W.3095·8950

29·4000W.3125·2950

ORDNANCE SURVEY MAPS

Types of Map Produced

The Ordnance Survey is a Government department, partly civil and partly military, which prepares plans and maps covering the whole country. Its headquarters are situated at Chessington, Surrey. These plans and maps are beautifully produced to an extremely high standard of accuracy. The municipal engineer uses Ordnance plans and maps for a wide variety of purposes, including base maps for sewerage proposals and existing sewers, water mains, street lighting, open spaces, planning schemes, etc.

Detailed information on the plans and maps produced by the Ordnance Survey was made available at a conference in 1963 (8).

The largest scale plans which are of special interest to the municipal engineer are the 1/1250 sheets, which cover the major built-up areas and these are being resurveyed to provide 47,000 plans and the fieldwork for 40,000 of them is complete. It is emphasised that continuous revision must be a high priority if these maps are to maintain their reliability in the face of considerable redevelopment.

The 1/2500 plans are to cover all urban areas and rural areas with the exception of mountain and moorland, where the six-inch to 1 mile map will be the basic scale of survey. Vast areas covered by the 1/2500 plans need resurveying, but it appears unlikely that this work will be completed before the early 1980's.

The completion of the whole of the six-inch basic areas which is undertaken by aerial survey cannot be expected before 1984. Recontouring at a 25-ft vertical interval of the six-inch maps derived from large scale surveys is proceeding. The six-inch maps are particularly useful to county surveyors, rural district engineers and town planners, in connection with the mapping of services, highway work, land uses and county map proposals covering rural areas.

Smaller scale maps produced by the Ordnance survey include 1/25,000, one inch to 1 mile, quarter inch to 1 mile and ten miles to 1 inch maps.

Other Ordnance Survey Services

The Ordnance Survey offers a number of other services, apart from the production of maps and plans (9), and these are now listed.

- (1) Lists of national grid retriangulation co-ordinates and descriptions of triangulation stations (location and land ownership).
- (2) Minor control albums, describing by diagrams or photographs, permanent traverse stations and revision points located on buildings, manhole covers, etc.
- (3) Bench mark lists describing bench marks and giving National Grid reference, altitude to 0.01 ft referred to Newlyn datum, height above ground level and date of levelling.

The positions and values of bench marks are shown on 1/1250 and 1/2500 scale National Grid plans, but the bench mark lists provide a more up-to-date source of information, as it is impossible for the Ordnance Survey to publish a new edition of a plan whenever a bench mark is destroyed or new levelling information becomes available.

- (4) Supply of National Grid co-ordinates of sheet corners of County series 1/1250 or six-inch sheets.
- (5) Libraries of aerial photography are maintained by the Ministry of Housing and Local Government in London and the Scottish Development Department in Edinburgh, from whom information and prints are obtainable.
- (6) Advance prints of surveyor's field documents can be obtained in exceptional circumstances, prior to initial publication of plans.
- (7) Holders of Ordnance Survey copyright licences may purchase copies

of published large-scale plans on tracing linen, Astrafoil or Perma-trace.

Municipal engineers often need to copy Ordnance Survey maps and plans in whole or in part. For this purpose a scale of royalty charges and licences operate, although licence holders are not, however, permitted to make facsimile copies of complete and unamended maps or plans.

GEOLOGICAL MAPS

The most useful geological map for general municipal engineering purposes is the lithological map, which shows the distribution of rock types, such as sand, clay, chalk, etc., and avoids reference to geological formations.

Geological maps are of two main types—solid and drift. Solid maps show only the underlying bedrock, whilst the drift maps show the strata overlying the bedrock but below the topsoil.

ESTIMATION OF EARTHWORK VOLUMES

There are various methods available for the computation of volumes of earthwork and this problem frequently arises in municipal engineering work.

Irregular areas of land can be determined by running a planimeter around the boundary of the area or by breaking the area down into a series of triangles, forming give-and-take lines around the boundaries. An average depth of excavation or fill may be found by weighting the depths according to their position (corners once, intermediate points on boundaries twice and all other intermediate points four times). An example is shown in *Civil Engineering Quantities* (10).

When calculating the volumes of excavation and fill for cuttings and embankments to accommodate roads, Simpson's rule can often be used to advantage. With this rule the area at intermediate even cross sections (nos. 2, 4, 6, etc.) are each multiplied by 4, the areas at intermediate uneven cross sections (nos. 3, 5, 7, etc.) are each multiplied by 2 and the end cross sections taken once only. The sum of these areas is multiplied by one-third of the distance between the cross sections to give the total volume. To use this formula it is essential that the cross sections are taken at the same fixed distance apart and that there is an odd number of cross sections (even number of spaces between cross sections).

In simpler cases involving 3 cross sections only, the prismoidal formula may be used, whereby:

$$\text{Volume} = \frac{1}{6} \times \text{total length} \times (\text{area of first section} + 4 \text{ times area of middle section} + \text{area of last section})$$

In recent years computers have been used to an increasing extent to calculate earthwork quantities in connection with highway schemes. This relieves the engineer of the tedious calculation of earthwork quantities and helps him to make a quick comparison of the quantities involved in two or three alternative schemes (11).

The computer determines the volumes of cut and fill along the proposed route using the average end area method, their net sum for plotting a mass-haul diagram and the stake lines. Before the computer can be brought into use the alignment must be chosen, cross sections surveyed at regular intervals, a grade-line determined and typicals specified (such as if the terrain is more than x feet below the grade elevation at a distance of y feet from the centre line, then apply the typical for a cutting, otherwise apply an embankment). The typicals and terrain data are fed into the computer together with special and basic programmes. The terrain data includes the grade elevation at the station, chainage or station number, alphabetical symbol indicating type of carriageway (balanced, superelevated turning to left or superelevated turning to right) and indication of a change in bulking or compaction factor or side slopes, if any. The computer reads this data from specially prepared sheets and processes it station by station, preparatory to determining the volumes, etc.

INVESTIGATION OF SITE CONDITIONS

Site investigation is undertaken to determine the type of strata beneath the site of proposed municipal engineering works. In addition, their physical and chemical properties must be established and conclusions drawn about their behaviour during excavation and during and after construction.

Various methods can be employed for this purpose, such as digging trial pits, borings, headings, *in situ* tests and geophysical methods. Each of these methods will now be briefly considered and further information can be obtained from the Code of Practice (12).

Trial Pits are slow and costly to form and are usually limited to depths of about 5 ft.

Boring is the most common method used today as it usually enables the required information about subsoil stratification and engineering properties to be obtained in a comparatively short time and at reasonable cost.

Commonly-used methods include boring with a post-hole auger for depths not exceeding 12 ft in fairly soft strata above the water table. Shell and auger boring is particularly popular: sectional boring rods are lowered by shear legs through the centre of a casing, previously driven by a monkey falling from a winch. The tools attached to the boring rods consist of augers for clay and shells, sand pumps for sandy strata and chisels for penetrating rock.

Other boring methods include mud rotary drilling, core drilling and shot drilling.

Headings may be used to explore deeply dipping strata and are usually less costly than trial pits.

In situ or Site Tests are of three main forms.

- (1) Direct bearing tests, in which trial pits are sunk to foundation level and loaded and the settlement noted. This method has definite weaknesses.
- (2) Penetration tests, in which a hollow tube containing a mandrel with a conical foot is driven into the ground. The degree of resistance to penetration of the foot is obtained by loading or by noting the number of blows of a hammer, falling through a fixed distance, that are needed to obtain 1 ft penetration of the mandrel. Rotation of a vane at the lower end of a guide tube (vane test) is useful in soft clays.
- (3) Pile tests, in which short piles are driven into the ground and the distance that the pile is driven by a blow of the pile-driver (the set) is noted, and this enables the resistance of the soil to be calculated,

using the Hiley formula—
$$R = \frac{nWh}{s + \frac{1}{2}c}$$

Where R = ultimate resistance of ground in tons to penetration of pile.

P = weight of pile, helmet and driving cap in tons.

W = weight of kinetic member of ram or hammer (monkey) in tons.

n = an efficiency coefficient which varies from 0.75 to 0.25, depending on type of soil and ratio P/W .

h = height of free fall of monkey in inches.

- s = set of pile (permanent penetration of pile per blow in inches).
 c = temporary elastic compression of the pile and cap and of the ground into which the pile penetrates.

Typical bearing pressures of different soils for structural foundations are:

	Soil	Pressure in ton/ft ²
<i>Non-cohesive:</i>	Compact gravel or sand and gravel	5
	Compact coarse sand	4
	Loose coarse sand	2
	Fine coarse sand	1
<i>Cohesive:</i>	Very stiff boulder clays and clay shales	6
	Stiff clays and sandy clays	4
	Firm clays and sandy clays	2
	Soft clays and silts	1
<i>Rocks:</i>	Hard sandstones and limestones	40
	Hard chalk	6

Geophysical Methods of site investigation are useful where investigations are to be carried to a great depth below the surface. They may also assist with the location of borings and provide information at intermediate points between borings. There are two principal methods—'electrical-resistivity' and 'seismic'.

(1) *Electrical-resistivity Method.* This method consists of passing an electric current through the ground via electrodes and finding the degree of resistance offered by the ground to the passage of the current. Various soils offer varying resistances to the passage of an electric current. The resistance of rocks to the flow of electricity is influenced considerably by the conducting properties of the saline solutions that fill the interstices of the rocks and the degree of saturation of the rocks.

In resistivity mapping, four electrodes are moved as a group with a constant distance between them. With this method it is possible to plot a graph showing the depth of overburden. With resistivity sounding the electrode spacing is varied and the electric current passes through the lower stratum and the depths of different rocks can be determined.

(2) *Seismic Method.* With the seismic method earth vibrations are produced by small explosions or hammer blows, and these vibrations are

timed on their passage through the strata below. Different rocks possess varying reflecting and refracting properties depending on their densities and elastic characteristics. Normally the harder the material and the greater its depth, the higher will be the velocity of transmission of the vibrations.

The detector, which converts ground movements into electrical impulses, is placed at varying distances from the source of the shock waves and the results are plotted on graph-paper. This method is generally used to trace the variations in depth of interfaces between different strata, and can sometimes be used to determine water tables.

Soil Sampling

It is necessary to take soil samples from all borings and trial pits to determine the soil profile and to provide material for testing purposes. Samples are of two main forms—*disturbed* and *undisturbed*. Disturbed samples are made up of excavated material taken at frequent intervals and placed in tins or glass jars with airtight lids, whereas undisturbed samples are in the solid intact form usually taken in 4-in. diameter steel tubes, 18 in. long and closed with screw caps, for soil mechanics investigations.

Each sample must be carefully labelled with its sample number, location, boring number, Ordnance datum of ground surface, depth below ground level, type of sample and general visual characteristics of soil. The foreman on the site will also keep comprehensive particulars of the work carried out, tools used, samples taken, tests performed, penetration resistance, water observations, etc.

Soil Testing

At the laboratory, the soil samples will be described in their correct technical terms, such as silty clayey sand, by soil engineers. The composition, strength and compressibility of the soils will be investigated, the actual tests varying with the type of job.

Grain size distribution is determined by sieving or sedimentation or a combination of both, and plasticity by a number of tests (liquid limit test, plastic limit test and shrinkage limit test). The mineralogical composition of the soil is determined using sieving apparatus, sedimentation glasses, hydrometer and liquid limit apparatus.

Water content is found with the use of electric ovens and balances. Complex tests using more complicated apparatus are needed to determine shear strength, compressibility, water content for optimum compaction, sulphate content, etc. Readers requiring detailed infor-

mation on these tests are referred to *Soil Mechanics for Road Engineers* (13).

The soils engineer will then consider the test results and the engineering problem and make his recommendations as to the type and depth of foundation needed and the permissible load. He may also advise on any special constructional methods that may be required, such as surrounding the excavation with sheet piling or the need for lowering the groundwater.

Boring Logs

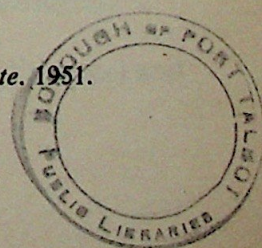
Table 3 shows typical entries in a boring log, recording particulars of conditions found on boring.

TABLE 3

Strata	Legend	Depth below ground level	Thickness of strata	Cohesion lb/ft ²	Angle of internal friction	Moisture content %	Standard penetration value
Ash		4"	4"				
Soil		5' 10"	5' 6"				
Soft sandy silty clay		8' 9"	2' 11"				
Light brown clay with small stones		12' 3"	3' 6"				
Light brown boulder clay		16' 2"	3' 11"				
Dark brown boulder clay (no water emitted below 24' 0")		35' 6"	19' 4"	750 at 16' 7" 380 at 24' 6" 0 at 35' 0"	0° 0° 20°	21 24 24	
Very fine sand with a trace of silt		43' 0"					109 at 38' 6"

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CHAPTER THREE

Highway Engineering

SOIL SURVEYS

A considerable amount of site investigation work is necessary to ensure that highway projects are satisfactorily located, designed and constructed. Soil surveys are concerned with the investigation of sub-surface materials, taking samples for laboratory soil testing and the preliminary examination and classification of soil types, sometimes coupled with *in situ* testing.

These investigations can follow one of the methods outlined in Chapter II—boring, trial pits and headings or geophysical methods. Trial pits are rarely used for depths exceeding 5 ft and are usually about 5 ft by 5 ft in plan.

For roadworks the trial pits or borings are normally spaced at about 300-ft intervals. The depth of borings should be approximately $1\frac{1}{2} \times$ height of embankments and depth of cuttings + 5 ft. The actual depth is however dependent upon many factors, including the purpose of boring, the presence or otherwise of unsuitable or unstable materials and the need to determine the nature of underlying strata at greater depths.

The soil samples may be *disturbed* or *undisturbed* and these will be taken in the manner outlined in Chapter II. In addition, it is usual to take a 1-pint sample of water from each boring for sulphate examination.

Soils are examined and classified in the field, following the broad classifications listed in Code of Practice 2001 (Table 1) which are as follows:

Coarse-grained and non-cohesive	}	Boulders, greater than 8 in. in diameter. Cobbles, 3 in. to 8 in. diameter. Gravels (no. 7 B.S. sieve to 3 in. diameter) and Sands.
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Fine grained	}	Silts
and cohesive		Clays
Organic		Peats

Additional descriptive information should also be given relating to type of mixture (e.g. silty sand), degree of softness, colour and texture. More detailed classification will result from laboratory tests, usually worked on the Casagrande system.

Where it is impracticable to obtain a suitable soil sample for laboratory testing purposes, it is necessary to carry out *in situ* tests using plate bearing tests, standard penetration tests, with a sampling spoon, or vane tests.

The subject of soil surveys and soil mechanics generally is a wide and complex subject and readers requiring further information are referred to the publications listed in reference 1 at the end of this chapter.

CONSTRUCTIONAL METHODS

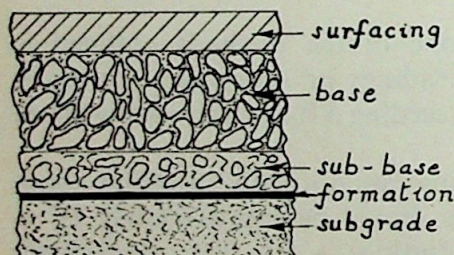


FIG. 22. Flexible road construction.

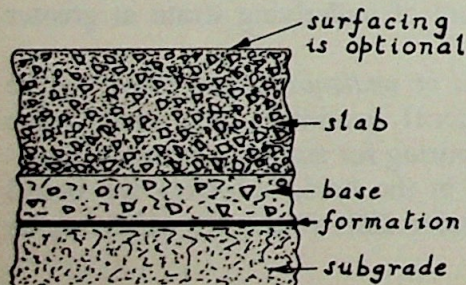


FIG. 23. Rigid road construction.

Road construction methods can be broadly subdivided into two main groups—*flexible* and *rigid*. The first group includes roads with a stone base and surfacing of tar or bitumen coated stones, whereas the best example of rigid or non-flexible construction is a concrete road slab. The type of construction adopted is largely influenced by the nature of the subgrade and the likelihood of subsidence due to mining or other causes.

Figs 22 and 23 illustrate these two forms of construction.

Subgrade

The subgrade is the natural formation or fill which directly receives the loads from the road itself, or pavement as it is more usually described. It must be able to carry these loads without excessive deformation. The

strength of a subgrade is expressed in terms of C.B.R. value (California bearing ratio). To obtain the C.B.R. value a cylindrical plunger with an end cross section of 3 in.². penetrates a sample of soil, at the rate of 1/20 in. per min. and the load required to cause a penetration of 0.1 in. or 0.2 in. is noted. This load when expressed as a percentage of a standard load is the C.B.R. value. The C.B.R. method usually provides a satisfactory method of determining the total thickness of a flexible road structure over average soils (2).

The main characteristics of the principal types of subgrade are listed in Table 4.

TABLE 4. CHARACTERISTICS OF SUBGRADES

<i>Characteristic</i>	<i>Highly plastic clays and silts</i>	<i>Average plastic clays, silts and soils</i>	<i>Fine sands with little clay</i>	<i>Sands and poorly graded gravels</i>
C.B.R. value	not exceeding 4	4 to 8	8 to 20	20 to 30
Drainage	Negligible	Poor	Good	Very good
Bearing value (ton/ft ²)	$\frac{1}{4}$ to $\frac{1}{2}$	$\frac{1}{2}$ to 1	1 to 2	2 to 2 $\frac{1}{2}$
Swelling and Shrinkage	High	Average	Very little	None
Frost susceptibility	Variable (15 in. total pavement thickness normally gives sufficient protection)	Variable (15 in. total pavement thickness normally gives sufficient protection)	Little (15 in. total pavement thickness normally gives sufficient protection)	None (minimum total pavement thickness of 12 in. required)
Compaction	Difficult—(best to use sheepfoot or pneumatic tyred roller)	Difficult—(best to use sheepfoot or pneumatic tyred roller)	Good (best to use 2 $\frac{1}{2}$ /8 ton roller)	Good (best to use 2 $\frac{1}{2}$ /8 ton roller)
Stability	Poor	Fair	Good	Very good

The surface of the subgrade is described as the formation and should be finished parallel with the final road surface. It is good practice to surface dress subgrades with a suitable tar, cutback bitumen or emulsion binder at the rate of 3 to 5 yd² per gal and either $\frac{3}{8}$ in. to $\frac{1}{4}$ in.

chippings at 100 to 120 yd² per ton or sand at 150 to 200 yd² per ton, consolidated with a 2½-ton roller.

Sub-bases

The sub-base is the layer of material between the road base and the formation in flexible construction. With rigid pavements the same layer is referred to as the base (between the formation and the road slab). The main functions of the sub-base are to reduce stress in the subgrade, protect the subgrade against frost, and prevent mud entering the pavement structure and damage being caused to the formation by constructional traffic.

It is generally recommended that sub-base material should have a C.B.R. value of not less than 15 per cent, be free from dust, have a maximum size of 3 in. and not be liable to damage by frost. Suitable materials are ashes, clinker, shale, gravel and hoggin. Suitable thicknesses of sub-base for estate and district roads range from 4 in. to 10 in., depending on the C.B.R. value and frost susceptibility figure for the sub-grade. The total pavement thickness will vary from 12 in. to 18 in. (3).

Road Bases

The road base is the layer of material in a pavement or road structure between the subgrade or sub-base and the surfacing. In the case of rigid pavements, such as concrete roads, the base acts as a working platform, provides uniform support to the concrete slab and acts as a regulating layer to ensure a uniform thickness of slab.

Typical Bases for Rigid Pavements

(1) *Granular Material.* Ashes, clinker, shale, slag, gravel, hoggin or crushed stone to a thickness of 3 in. to 6 in. depending on the nature of the subgrade, compacted with a 6 to 8-ton roller (deadweight).

(2) *Lean Concrete.* The aggregate is usually washed gravel or stone to B.S. 882 (Table 3) or slag to B.S. 1047, in the ratio of 1 part of cement to 15/20 parts of gravel or 1 part of cement to 18/24 parts of other aggregates, with a water content of 5 to 6 per cent by weight. Lean concrete can be mixed in normal type concrete mixers provided the proportion of fines does not exceed 45 per cent, otherwise pan or paddle-type mixers or pugmills should be used. It is difficult to obtain a closely-knit surface if the sand content of the mix is less than 30 per cent.

Lean concrete is compacted in 4 to 8 in. thick layers within 1½

hours of laying with a $6\frac{1}{2}$ to 20-cwt vibratory roller, followed by an 8 to 10-ton roller (deadweight). It is generally cured by coating with 55 per cent emulsion at the rate of 6 to 8 yd² per gal. It should attain a minimum strength of 1,400 lb/in² at 28 days.

(3) *Cement-bound Granular Base*. This base material is made up of gravel or all-in-ballast to a maximum size of 2 in. mixed with 5 per cent by dry weight of cement. It can only satisfactorily be mixed in paddle, pan or other specialised types of mixer and is therefore only really suitable for use on motorway and similar large-scale projects. It is usually laid in $3\frac{1}{2}$ to 6 in. layers and must be compacted within 45 min of laying with a $2\frac{1}{2}$ -ton roller followed by an 8-ton roller. It is generally cured by coating with emulsion in the same way as lean concrete and should attain a minimum strength of 1,200 lb/in² at 28 days.

(4) *Soil Cement*. The basic material may consist of naturally occurring soil, a washed or processed granular material, crushed rock or slag or an industrial waste product, such as pulverised fuel ash, or a combination of some of these materials which gives a suitable basic material for the soil cement process. The material must be well graded within certain specific limits as indicated in the Ministry of Transport specification (2).

The proportion of cement varies between 5 and 15 per cent by weight of the mix, and hydrated lime or calcium chloride are sometimes added.

Paddle or pan type mixers are suitable for mixing soil cement where stationary plant is to be used. Where suitable soil exists on the site of the road it is customary to use mix-in-place construction. With plastic soils a single-pass type mixer is used, whilst with non-plastic soils, both single and multiple pass-equipment can be used. With mix-in-place construction the cement is spread ahead of the mixer after the soil has been pulverised, and mixing then continues until the required depth and uniformity of processing is obtained.

Soil cement is usually laid in $3\frac{1}{2}$ to 6 in. layers and the method of compaction varies with the type of soil and plant used. The most usual form of compaction is to start with a 2 to 3-ton smooth-wheeled roller followed by an 8 to 10-ton similar roller.

Curing is performed by surface dressing the road base with tar, bitumen or emulsion at the rate of 3 to 4 yd² per gal and with $\frac{3}{8}$ in. chippings at 100 to 120 yd² per ton (4).

Typical Bases for Flexible Pavements

(1) *Dry-bound Granular Base*. The materials used are principally igneous rock, limestone and slag, $2\frac{1}{2}$ in. to $1\frac{1}{2}$ in. in size topped with a 1-in. layer

of material graded from $\frac{3}{8}$ in. to dust. It is usually compacted with a $2\frac{1}{2}$ -ton roller, followed by a vibrating plate compacter and an 8 to 10-ton smooth-wheeled roller.

(2) *Water-bound Granular Base.* The materials used consist of igneous rock, limestone, slag and certain gravels, 2 in. or $1\frac{1}{2}$ in. in size with 2 to 5 per cent water content. It is usually compacted with an 8 to 10-ton smooth wheeled roller with a minimum of 10 passes.

(3) *Stone Pitching.* This consists of stones 8 in. to 10 in. in length, hand laid on end, knapped and blinded. The base is consolidated with an 8 to 10-ton roller. This form of construction is little used today due to the difficulty of securing suitable material or labour and the high cost involved.

(4) *Hardcore.* Any suitable hard material can be used usually blinded with hoggin or ashes and compacted with an 8 to 10-ton roller. It is, however, only really suitable for minor roads.

(5) *Low-binder Macadam.* The aggregate consists of crushed rock, limestone, slag or gravel, 2 in. in size, bound with a high viscosity tar or straight run bitumen at the rate of about 5 gal per ton. It can be machine or hand-laid and is compacted with an 8 to 10-ton roller. The introduction of the low binder content serves to help machine-laying and gives improved compaction and stability qualities.

(6) *Base-course and Single-course Tar or Bituminous Macadam.* The aggregate consists of crushed rock, limestone, slag or gravel, 2 in. or $1\frac{1}{2}$ in. in size, bound with 50 evt tar or penetration grade bitumen. It is laid warm by hand or machine and compacted with an 8 to 10-ton roller. In addition to their use for road bases in new construction, they are also suitable for use as strengthening courses to existing roads (see British Standards 802, 1241, 1621 and 2040) (5).

(7) *Tar or Bitumen-bound Granular Base (close-textured tar or bitumen macadam).* The aggregate consists of igneous rock, limestone, slag or gravel, $1\frac{1}{2}$ in. or 1 in. in size, bound with 50 or 54 evt tar at 3.5 to 5.5 per cent or 100 or 200 penetration bitumen at 3 to 5 per cent depending on the type of aggregate. It is machine laid hot in multi-layer construction in 2 to 3-in. layers and compacted with an 8 to 10-ton roller

operating immediately behind the machine. The close-textured mixtures possess greater strengths and are often referred to as 'dense bituminous bases'.

BITUMINOUS SURFACINGS

Bituminous surfacings are used extensively in road construction as they provide a smooth non-skid, abrasion-resistant and jointless surface which possesses colour and texture and has good cleansing and surface water run-off properties. Aggregates consist of crushed rock, slag or gravel (see British Standards 63, 410, 812 and 1984).

The thickness of bituminous surfacings varies with the type of road and its probable traffic flow. Very heavily trafficked main routes require a minimum thickness of surfacing of 4 in. laid in two courses, main town roads need a 3-in. thick surfacing in two courses, whilst for minor estate roads such as culs-de-sac, $2\frac{1}{4}$ in. thickness in two courses or 2 in. thickness in a single hot-laid course will suffice (5).

Binders

There are four main types of binder:

(1) **Tar** is derived from coal and is resistant to petroleum oils. It is particularly suitable for car parks and bus stops. Viscosity is expressed in degrees Centigrade, evt, in steps of 4°C (see British Standards 76 and 616).

(2) **Straight-run Bitumen** (penetration grade) is derived from petroleum; needs higher temperatures and greater care in laying than cut-back bitumen but produces a more durable and malleable material. Viscosity is expressed in penetration at 25°C (see British Standard 3235).

(3) **Cut-back Bitumen** is a blend of straight-run bitumen (penetration grade) and volatile flux oils. It can be handled at lower temperatures than straight-run bitumen and can be stored for short periods for patching work, but it is expensive and easily suffers damage from overheating. Viscosity is expressed in seconds, stv at 30°C and 40°C .

(4) **Blends** are mixtures of tar and bitumen. The addition of up to 10 per cent of bitumen to tar is generally believed to give the tar additional body, greater ductility at low temperatures and better weathering qualities. Conversely, the addition of 10 per cent tar to bitumen is generally

believed to assist the spread of binder on the stone and reduce stripping, except in the case of limestone aggregate.

Materials

Bituminous surfacings include a number of different materials such as warm-laid macadams, cold asphalt, hot-laid dense macadams, hot-rolled asphalt, mastic asphalt and compressed rock asphalt. The main characteristics and advantages of each of these materials will now be considered:

Warm-laid Macadams are usually cheaper but have a shorter effective life than hot-laid surfacings. They are particularly suitable for low-cost jobs, less heavily trafficked roads and where there is a shortage of skilled labour. It should be possible to use a local stone as aggregate and a choice will have to be made between tar and bitumen as binder. Tar is cheaper in first cost but the bitumen has a longer life. Tar offers more resistance to petrol and oil droppings, but bitumen is satisfactory through a larger range of laying temperatures and provides greater resistance to deformation in hot weather.

Warm-laid macadams can be laid in different ways, although all are compacted with 6 to 10-ton rollers, to perform a number of functions.

Two-course consists of a base-course compacted to 2¼ in. to 3¼ in. in thickness and a wearing course ¾ in. to 1½ in. thick, preferably sealed with cold asphalt or pre-coated grit and is well suited for the reconstruction of existing roads and surfacing of new roads to carry light to medium traffic.

Single-course consists of a wearing course to a compacted thickness of not less than 2 in., sealed as before, and is suitable for surfacing and resurfacing work for light to medium traffic.

Thin-wearing (carpet course) is laid to a compacted thickness of ¾ in. to 1½ in. and is suitable for restoring riding qualities of roads.

Multiple-course (base-course material) is laid in 3 to 4 in.-thick layers in reconstruction for superelevation and in evening out large irregularities. Tarmacadam (B.S. 802 and 1241) has a life of 5 to 7 years and bitumen macadam (B.S. 1621 and 2040) has a life of 6 to 8 years, but these can be extended by periodic surface dressing.

Cold Asphalt consists of a mixture of bitumen and crushed igneous rock, limestone or slag aggregate in fine and coarse grades to B.S. 1690.

In the fine grade all aggregates pass a $\frac{1}{4}$ in. sieve and a roughened finish is often obtained by rolling in $\frac{1}{2}$ in. or $\frac{3}{4}$ in. pre-coated chippings at 120 to 250 or 90 to 200 yd² per ton respectively with a roller weighing not less than 5 tons. This material has a number of uses which are described.

- (1) As an impervious wearing course, $\frac{1}{2}$ in. to $\frac{3}{4}$ in. thick on a warm or hot-laid bituminous base course;
- (2) As a carpet coat on worn-out bituminous or badly worn concrete surfaces and on sett paving;
- (3) For patching up to 1 in. in depth (base course material at lower depths);
- (4) For blinding and sealing a temporary running surface on base-course material and open-textured bituminous wearing-courses.

The course-grade material is used for wearing courses, $\frac{3}{4}$ in. to 1 $\frac{1}{4}$ in. thick, but without chippings on medium trafficked roads. Cold asphalt has a life of up to 10 years.

Dense Base-Courses. Dense-bitumen and tar-bound base-courses have excellent load-spreading qualities, and provide an economical and almost impervious base-course. They are laid hot as single-course or multi-course work, preferably by machine. The material is compacted with a 3 to 6-ton roller immediately after the machine, followed by an 8 to 10-ton roller.

Dense Bitumen (wearing course). This material is covered by B.S. 1621 and is suitable for all new roads except motorways and the like. It has a close-textured finish and a wide range of bitumens permitting a large temperature range for laying purposes. It is laid warm to hot, preferably by machine unless small quantities only are involved. Unless the base is fresh it should receive a tack-coat of bitumen emulsion to B.S. 434 (class 1c), at the rate of 12 to 15 yd² per gal.

Dense Tar Surfacing is a hot-laid impervious wearing-course with a high-viscosity tar binder. It is produced in two grades with stone contents of 50 and 35 per cent, and is best laid by machine. It is compacted with a 3 to 6-ton roller immediately after the machine, followed by an 8 to 10-ton roller. When laid on a fresh base course, this must be of hot-laid dense material. Dense tar surfacing provides a good non-skid and durable surface which is highly resistant to petrol and oil droppings.

Hot-rolled Asphalt gives a dense, impervious and non-skid surface and is almost entirely machine-laid. Colours other than black can be obtained by using coloured aggregate or pre-coated chippings. The appropriate British Standard is B.S. 594.

*Hot-rolled asphalt is made up of four main components.

- (1) Asphaltic cement—fluxed lake asphalt, petroleum bitumen or an equal mixture of both which acts as a binder;
- (2) Fine aggregate—natural sand, crushed coarse aggregate or a mixture of both; this gives non-skid qualities and added stability;
- (3) Coarse aggregate (stone content)—rock, blast-furnace slag or gravel giving added stability and resistance to wear;
- (4) Filler—limestone or Portland cement, giving density and stiffness.

Hot-rolled asphalt is generally laid by a specialist contractor and the method of laying is similar to that described for hot-laid dense macadam. It is advisable to provide a tack-coat of bituminous emulsion at the rate of 10 to 16 yd² per gal on smooth concrete, asphalt or bituminous surfaces. A roughened surface is obtained by applying pre-coated chippings prior to rolling on mixtures with a stone content not exceeding 45 per cent.

Mastic Asphalt may have a natural rock aggregate (B.S. 1446) or a limestone aggregate (B.S. 1447), together with a binder of asphaltic cements and either petroleum bitumen, fluxed lake asphalt or an equal mixture of both. After mixing, the material is usually cast into $\frac{1}{2}$ cwt blocks for subsequent re-heating at a plant or on the site of the job.

Its sole use is as a wearing-course for roads and footpaths—the road grade contains 35 to 54 per cent of $\frac{1}{8}$ in. to $\frac{1}{2}$ in. rock chippings, whilst the footpath grade contains 25 per cent of $\frac{1}{8}$ in. down gravel grit. The thickness varies from 1 in. to 2 in. and is usually hand-laid with floats in two courses over concrete or setts. It is ideal for city roads and paths, hard-standings and markets. Three main forms of surface finish are used.

- (1) Roughened—using $\frac{1}{2}$ in. or $\frac{3}{4}$ in. chippings;
- (2) Sanded—a thin coat of sand is rubbed into the asphalt with floats;
- (3) Indented—using a hand crimping roller.

Compressed Rock Asphalt consists of limestone rock naturally impregnated with bitumen ($7\frac{1}{2}$ to 13 per cent). It is compacted by hand-punning and is used solely as a wearing-course on very heavily trafficked streets, $1\frac{1}{2}$ in. to 2 in. in thickness. The surface finish may be either smooth

(sealed with a smoothing iron and brushed with cement or limestone powder) or roughened (igneous rock chippings on a tack coat and lightly rolled). It is considered to be the very best of all road surfacing materials and no surface wear takes place until 5 to 10 years after it is laid. It is only its high cost that prevents its more widespread use.

The principal trade associations connected with bituminous surfacings are: The Asphalt Roads Association, the Federation of Coated Macadam Industries and the British Road Tar Association. There are also associations concerned with granite and whinstone, slag, limestone and sand and gravel.

CONCRETE ROADS

The stresses developed in concrete pavements or road slabs arise mainly from the vertical reactions of wheel loads and from changes in temperature and moisture content of the concrete. The design of concrete roads generally provides for the control of cracks through expansion joints, and steel fabric reinforcement is usually incorporated to hold together the various parts of any cracked slabs. The C.B.R. method is sometimes used to determine the required thickness of slab, which normally varies between 6 in. and 10 in.

Materials

The cement should comply with British Standard 12 for ordinary or rapid-hardening Portland cement or 915 for high alumina cement. Aggregates should comply with British Standard 882 and the sand or fine aggregate should be coarse, sharp and less than $\frac{3}{16}$ in. in size, and is best obtained from stone crushers, sandpits or rivers; sea-shore sand should always be avoided. Coarse aggregate may be washed gravel, whinstone, basalt, granite, limestone or other suitable material, roughly cubical in shape with sharp edges and often of $\frac{3}{4}$ in. or $1\frac{1}{2}$ in. maximum size.

Design Factors

The principal design factors relating to concrete roads are the form of base, the thickness of the concrete, the mix of concrete, whether one- or two-coat construction is to be adopted and the amount and position of the reinforcement. Each of these aspects will now be considered.

Form of Base. As described earlier in this chapter, the most common

form of base is a layer of granular material, such as ashes, hoggin or crushed stone, varying in thickness from 3 in. for normal subgrades to 6 in. for poor subgrades. Alternatives are lean concrete and cement-bound granular bases and cement stabilised subgrades.

Granular bases are covered with a layer of waterproof building paper, usually to B.S. 1521 (class B), or plastic sheeting (250 grade), to prevent the concrete mixing with the material below it and the passage of water from the concrete to the base material.

Thickness of Concrete Slab. For normal subgrades and light traffic (45–150 commercial vehicles per hr in both directions) the thickness of the concrete road slab would be 6 in., provided it contained not less than 7 lb per yd^2 of fabric reinforcement. The thickness can be reduced to 5 in. for very light traffic (below 45 vehicles per hr). At the other end of the scale, for roads carrying very heavy traffic (over 4,500 vehicles per hr) a thickness of 10 in. is recommended in *Concrete Roads—Design and Construction* (6), provided not less than 14 lb per yd^2 of fabric reinforcement are provided.

These thicknesses should be increased by 1 in. for subgrades which are highly susceptible to non-uniform movement, on embankments more than 4 ft high and on subgrades where the water table may rise to within 2 ft of the formation.

Slab thicknesses are affected by properties of the soil, inclusion or omission of base or steel reinforcement and the intensity of traffic to be carried.

Mix of Concrete. A common aggregate cement ratio is 6:1 by weight with a water cement ratio not exceeding 0.55. Mixes are sometimes specified by volume or weight, such as 1:2:4, and on occasions the concrete is specified by the minimum strength which must be attained in lb/in^2 at 7 days.

The concrete is best mixed in batch type mixers or truck mixers.

Number of Coats. The majority of concrete road slabs are constructed in one thickness or coat. Two-coat work is more complicated to perform as well as being more costly, although it can be an advantage on heavily trafficked roads where an exceptionally hard-wearing surface is required. In these circumstances the top coat will consist of a thinner layer containing granite or other hard-wearing aggregate.

Steel Reinforcement. A single layer of steel fabric reinforcement is usually inserted in the road slab about 2 in. below the surface of the slab. One

of its main functions is to hold the fractured portions of the slab together if it cracks, but it also assists in resisting differential stresses arising during the hardening process, reduces the need for closely-spaced joints and extends the useful life of slabs. The steel fabric reinforcement should comply with B.S. 1221 and should desirably be delivered to the site in mats and not rolls, as the reinforcement from rolls tends to curl under vibration. A commonly used fabric is that weighing 7 lb per yd^2 for 6 in. road slabs.

Constructional Methods

The most common form of construction of concrete pavements is continuous construction, broken up at intervals by transverse expansion joints. In the case of unreinforced concrete road slabs transverse contraction joints, usually in the form of dummy joints, are needed at 15-ft intervals, but with reinforced slabs expansion joints only are needed at a maximum spacing of about 80 ft. Expansion joints permit the concrete to expand when the temperature rises above that prevailing when the concrete was laid, whereas contraction joints are breaks in the structural continuity of the concrete and allow the concrete to contract when it falls below the laying temperatures.

The expansion joints are usually about $\frac{3}{4}$ in. in width with the arrises rounded, filled to within $\frac{1}{2}$ in. of the road surface with non-extruding material such as fibre board, and sealed with bitumen or some other suitable sealing compound.

Where roads exceed 16 ft in width, longitudinal joints are generally introduced and these often take the form of 'dummy' joints. A common form of 'dummy' joint is a groove about $\frac{1}{4}$ in. wide and 2 in. deep formed in the top of the slab before the concrete has hardened, and the space so formed is filled with sealing compound. Longitudinal joints may merely be vertical butt joints, without any joint filler, but are often painted with hot tar, bitumen or cold emulsion. Construction joints are made when work is unexpectedly interrupted, and in these the reinforcement is carried across the joint and a sealing groove provided at the top of the joint.

Dowelled joints are sometimes used to transmit loads from one slab to the next. Allowance must be made for movement of the slabs by securing the dowel bars in one slab but leaving them free to move in the adjacent slab. The dowel bars are of mild steel, usually about $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. in diameter and with a length varying between 20 in. and 28 in. according to diameter, placed at half the depth of the slab and spaced at intervals of about 12 in. The dowels must be fixed at right angles to the joint line and

be perfectly level; with one part embedded in a slab and the other part painted with bitumen, wrapped in paper or fitted in a sleeve, to prevent it adhering to the concrete. This end of the dowel bar should be enclosed by a cardboard or metal cap to allow for movement with changes of temperature. The expansion joint filler has holes drilled in it through which the dowel bars pass. Fig. 24 illustrates a typical dowelled joint.

Another form of construction is that known as the alternate bay method, in which the road is constructed in short bays about 20 ft in length. Alternate bays only are first concreted in and after they have set, and the initial contraction has taken place, the intermediate bays are laid. Thin expansion joints are placed between the bays.

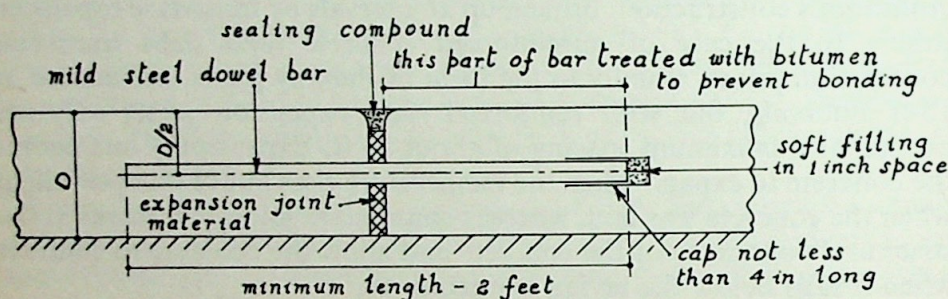


FIG. 24. Dowelled joint.

The concrete can be tamped off the kerbs or off side forms of steel or timber, and vibrating tampers are generally used for this purpose. On large jobs spreading machines or pavers will probably be used. Experiments are also proceeding with the use of a slip-form paver, which uses a moving side form and guides itself electronically along a wire at the side of the carriageway.

Curing Concrete

Concrete must not be permitted to dry out quickly or it will lose part of its strength and surface cracks will develop, particularly in hot weather or with cold drying winds. The surface of the concrete must therefore be protected from sun and wind and be kept moist.

A method advocated by the Ministry of Transport is to apply a suitable resinous curing compound to the finished surface of the concrete at the rate of 20 to 25 yd² per gal. In addition it is recommended that the concrete is protected against the effects of sun and rain during setting by covers of opaque and waterproof material of white colour externally, supported on a suitable framework (2).

No vehicular traffic should be allowed on the finished surface of the concrete within 20 days of completion, when ordinary Portland cement is used, or 10 days where rapid-hardening cement is used (6). Furthermore, concrete must not be laid when the temperature is below 38°F (3°C).

Concrete Road Failures

Concrete roads have failed due to a variety of causes, such as insufficient expansion or other joints, settlement or failure of the subgrade, faulty materials and workmanship, weak concrete, inadequate curing, abnormal traffic, etc.

It is imperative that concrete roads be adequately maintained, and in the autumn all open joints and cracks should be sealed and badly worn surfaces coated with a bituminous carpet.

Prestressed Concrete Roads

The advantages of prestressing concrete road slabs are that crack formation is prevented or controlled, expansion joints can be more widely spaced resulting in better riding qualities, and the slabs can often be thinner, subject to a minimum of 6 in.

This form of construction does, however, make it difficult to secure access to services below the concrete slab and the stressing has to be performed after laying the concrete, so that it is sometimes necessary to leave jacking bays between the slabs.

KERBS

The main functions of road kerbs are to resist the lateral thrust of the carriageway (particularly in flexible construction), to define the limits of the carriageway (this is especially important after dark and in foggy weather), to direct the flow of surface water to gullies, etc. and to define, support and protect footpaths and verges.

The most common form of kerb is in precast concrete to B.S. 340, and can be manufactured using Portland, blast furnace or high alumina cement and natural stone or slag aggregate and may be coloured. Manufacturing processes include cast, vibrated and hydraulically pressed—the latter giving the strongest kerbs which are recognised by their patterned faces.

Precast concrete kerbs are made in 3-ft lengths and in four standard sections—bullnosed (with $\frac{5}{8}$ in. to $\frac{3}{4}$ in. radius edge), splayed (3 in. wide

× 3 in. deep), half-battered (4 in. deep) and half-section (half-battered). The last two sections are illustrated in Fig. 25, and the most commonly used sizes are 5 in. × 10 in. and 6 in. × 5 in. respectively. Radius kerbs are manufactured to radii of 3, 6, 8, 10, 15, 20, 25, 30, 35 and 40 ft for external kerbs and 6, 10, 15, 20, 30 and 40 ft for internal kerbs.

Bullnosed and half-battered kerbs are used extensively for urban roads, whereas splayed kerbs are frequently used on dual carriageways and rural roads generally. Kerbs are usually laid to give a 4 in. minimum face to the carriageway.

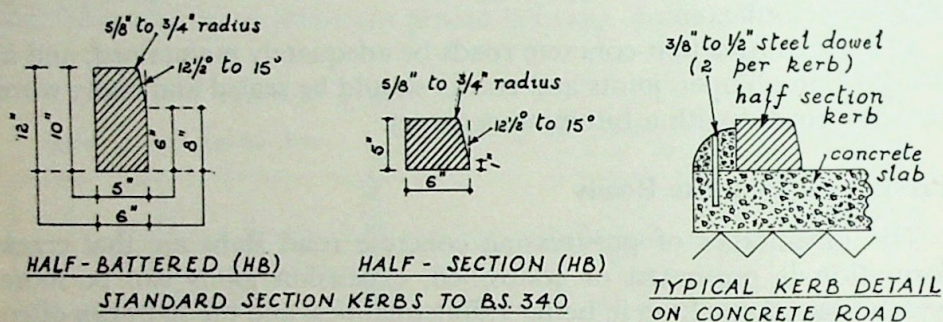


FIG. 25. Kerbs.

With flexible roads (pavements) it is usual to lay full-section kerbs (4 in. × 10 in. to 6 in. × 12 in.) beside the road to take the lateral thrust. They are usually bedded on a $\frac{1}{2}$ to 1 in. layer of cement mortar on a concrete (1:3:6) foundation, 4 in. to 6 in. thick, and backed up with similar concrete, 4 in. to 5 in. thick, to within 3 in. of the top of the kerb. Sometimes the kerbs are laid on a fresh semi-dry concrete foundation, thus dispensing with the need for a mortar bed. The kerbs may be butt jointed without the use of mortar, or alternatively the joints may be formed of mortar and pointed, when expansion joints should be provided at 100-ft intervals.

With rigid road or pavement construction it is better to use half-section kerbs on a mortar bed, $\frac{1}{2}$ in. to 1 in. thick, laid directly on the concrete road slab. To give ample support to the kerbs it is good practice to provide two $\frac{3}{8}$ in. to $\frac{1}{2}$ in. diameter steel dowel bars, 5 in. to 6 in. long, to each length of kerb and driven 3 in. into the concrete while it is still green and backed up with concrete (1:3:6), as shown in Fig. 25. This form of construction prevents water entering between the kerb face and the edge of the road slab.

Kerbs can also be formed in stone—granite or whinstone to B.S. 435

or sandstone to B.S. 706, although stone kerbs have been largely superseded by precast concrete kerbs. Stone kerbs can be finished in various ways on their exposed faces, for instance granite kerbs may be fine picked, fair picked or single axed (nided), or rough punched, whilst sandstone kerbs may be fine axed, coarse axed, rough punched or sawn, and they vary in size from 4 in. $\times$ 10 in. to 8 in. $\times$ 12 in. in section, with lengths varying from 1 ft 9 in. to 2 ft 6 in.

CHANNELS

The main functions of channels are to help surface-water run-off, assist in defining the limits of the carriageway and to facilitate road sweeping. With flexible roads they also serve to strengthen the edges of the carriageway and to prevent damage occurring to the kerbs during rolling of the carriageway. On rural roads flush kerbs may be used where verges adjoin the carriageway and vertical kerbs would be out of harmony and could impede surface-water drainage.

The most commonly used channels are precast concrete to B.S. 340 of 10 in. $\times$ 5 in. rectangular section on a concrete foundation, 5 in. to 6 in. thick. Other materials include scoriae blocks of cast molten slag usually about 8 in. $\times$ 4 in. $\times$ 4 in. in size; mastic or hot-rolled asphalt without any pre-coated chippings, 8 in. to 12 in. wide, and *in situ* concrete usually about 8 in. to 10 in. wide, finished with a wood or steel float.

EDGING

Precast concrete edging is often provided at the back edge of flexible footpaths to give support and define the edge of the path, particularly where the adjoining ground is at a lower level than the path. Precast concrete edging is made to B.S. 340 in sizes ranging from 2 in. $\times$ 6 in. to 2 in. $\times$ 10 in. in 3-ft lengths, with the tops finished to half-round, square, chamfered or bullnosed sections. The edgings are usually bedded on and backed up with a 3-in. thickness of semi-dry concrete and they are normally laid with butt joints.

QUADRANTS

Quadrants are manufactured in standard sections to match the kerbs, and precast concrete quadrants are in solid form to B.S. 340 with 12 in.

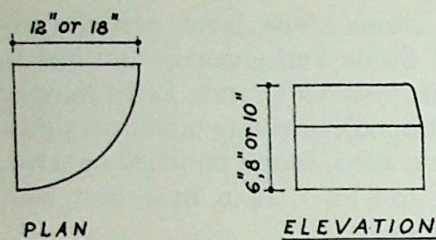


FIG. 26. Quadrants.

or 18 in. radii to outer face and depths of 6 in., 8 in., or 12 in., as illustrated in Fig. 26. They are particularly useful at the junctions of kerbs and setts at footpath crossings.

SETTS

Setts are usually of granite or whinstone, varying in depth from 4 in. to 6 in., in width from 3 in. to 5 in. and in length from 5 in. to 9 in., and are bedded on a concrete foundation and usually grouted in cement mortar or a suitable compound. They are often used to define the edges of carriageways in rural areas, and may form a small sloping abutment for this purpose; a single course is frequently provided between different surfacings, such as concrete and tarmacadam, at a road junction.

FOOTPATH CONSTRUCTION

Footpaths can be constructed in a variety of different ways and the principal methods of construction are now described.

Precast Concrete Paving Slabs

Precast concrete paving slabs or flags are widely used in the shopping streets of towns and to a considerable extent in residential and industrial areas. The best slabs are hydraulically pressed, although some are vibrated. All paving slabs should comply with B.S. 368 and can be made with a variety of aggregates and to various colours and surface finishes.

The standard sizes of paving slab are 3 ft $\times$ 2 ft, 2 ft 6 in. $\times$ 2 ft, 2 ft $\times$ 2 ft and 1 ft 6 in. $\times$ 2 ft, in both 2 in. and 2½ in. thicknesses. Colours include natural and pigmented to such colours as red, buff, cream, grey and black (B.S. 1012), whilst the finish may be mesh, pimple or chequer pattern.

The slabs are usually laid on a 3 in. or 4 in. thick base of ashes, rolled with a 2½-ton roller or a 6 to 10-cwt vibratory roller, and a ½ in. to 1 in. bed of sand, lime mortar or gauged mortar. It is desirable

to use a solid bed when laying the mortar in preference to the 5-pat system, to reduce the risk of uneven settlement of slabs. In town and city centres where vehicular traffic may mount the footpath, it is good policy to lay the slabs on a 3-in. sub-base of ashes and a 4-in. bed of concrete, to reduce the risk of broken slabs.

The usual amount of bond is 6 in., although this may be increased to 12 in. on exceptionally wide footpaths, and the normal crossfall is $\frac{3}{8}$ in. in 1 ft. After laying, the slabs are grouted in with lime or cement mortar to give a solid job.

Paving slabs are an expensive method of footpath surfacing, are easily damaged by vehicles and need skilled labour, which is in short supply, to lay them. They are, however, very attractive in appearance, durable, and fairly easily lifted to gain access to underground services and readily reinstated.

Stone and Reconstructed Stone Paving Slabs

Natural stone flags or paving slabs are little used today on account of their relatively high cost, although they are hard-wearing, relatively non-slip and of various colours and textures. The commonest variety is York stone, which is a light brown or blue sandstone, although Portland stone (a greyish white oolitic limestone) is sometimes used, but the latter is not so hard-wearing as York stone. York stone slabs are supplied in thicknesses ranging from 2 in. to 3 in., in 24 in. to 30 in. widths and random lengths.

Reconstructed stone slabs contain natural stone both as fine and coarse aggregates, the stone giving colour and non-slip qualities. They are made in a variety of different sizes and there are a number of non-standard shapes available for patterned-work, such as hexagonal, triangular and circular, which are usually surrounded by asphalt, tarmacadam or cobbles.

In situ Concrete

In situ concrete is particularly well suited for large areas and footpaths to houses. The usual mixes range from 1:2:4 to 1:3:6 using a $\frac{3}{4}$ in. graded aggregate and the concrete is normally 3 in. thick. It is advisable to provide dummy joints at about 6-ft intervals and expansion joints at about 30-ft intervals.

A variety of surface finishes are available including tamped, rolled with a crimping roller leaving pyramidal depressions, brushed aggregate, pigmented, and surface dressing with coloured chippings lightly

tamped into the concrete. It is a relatively cheap form of footpath surfacing but cannot be satisfactorily opened up and reinstated in order to gain access to underground services.

Bituminous Surfacing

A common footpath surfacing is tarmacadam tarpaving in accordance with B.S. 1242, using a crushed rock or slag coarse aggregate and a binder of tar or tar-bitumen mixture. It may be laid warm or cold on a base of clinker, hardcore or other suitable material, 2 in. to 3 in. in thickness.

Tarpaving may be laid in a single course, $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. thick, or in two courses with a total thickness of $1\frac{3}{4}$ in. to 3 in. ($1\frac{1}{4}$ in. to $2\frac{1}{4}$ in. base course and $\frac{3}{8}$ in. to $\frac{3}{4}$ in. wearing course). The tarpaving should be rolled with a roller weighing not more than 4 tons to a crossfall of not less than 1 in 48. This constitutes a relatively cheap, non-slip and easily constructed footpath surfacing which can be reinstated fairly easily, although it needs periodic surface dressing. The surface can be treated with grit or fine cold asphalt.

Another alternative form of construction, which is becoming increasingly popular, is a single course of fine cold asphalt to B.S. 1690, laid on hardcore, concrete, soil-cement or other suitable base. A tack coat of bitumen emulsion (10 to 16 yd² per gal), should precede the asphalt, unless the latter is being laid on a recently laid base course. The thickness should be within the range of $\frac{3}{8}$ in. to $\frac{3}{4}$ in., and the asphalt should be consolidated with a 7 to 50-cwt roller.

After initial consolidation, $\frac{1}{2}$ in., $\frac{3}{4}$ in. or 1 in. pre-coated chippings are sometimes applied and then rolled or otherwise pressed into the asphalt. Fine cold asphalt gives a denser and more hard-wearing surface than tarpaving.

Cobbles, Setts, Bricks

These smaller paving units are used on occasions to give interest, for demarcation purposes, to form drainage channels, to pave small irregular areas and to discourage the passage of vehicles and pedestrians.

Cobbles are obtained from river beds, beaches and gravel quarries and are hard-wearing and have a good texture. They are often about 2 in. to 3 in. in size but can be 6 in. to 9 in. in areas subject to vehicular traffic. For lightly trafficked areas, cobbles are usually laid on a fine gravel or ash bed with the intervening spaces filled with a dry cement and sand mix brushed in and sprayed with water. For heavily trafficked areas the cobbles are usually laid on a semi-dry concrete bed about 4 in.

thick, so that the cobbles extend above the concrete for about one-third of their depth.

Setts are usually of granite or whinstone and are generally either hammer-dressed (left roughly rectangular) or nidded (chisel-dressed to a true rectangle). They are extremely hard-wearing with good textures and colours and are usually laid to a crossfall of about 1 in 36 on a concrete base with a 1 in. cement mortar bed, with the joints between the setts filled with $\frac{1}{4}$ -in. chippings and grouted with pitch or pitch/tar (3:1) compound. Cement mortar can be used for jointing in pedestrian areas.

Engineering bricks and brick pavers are suitable for paving in a variety of bonds and patterns. They are usually laid on a concrete base with a $1\frac{1}{2}$ -in. bed of semi-dry cement mortar (1:4) with $\frac{1}{4}$ -in. to $\frac{3}{8}$ -in. joints between the bricks.

Gravel

Gravel is used for surfacing lightly used pedestrian areas in rural districts, landscaped areas, around trees in car parks and in shaded areas where grass will not thrive. The formation is usually treated with a weed killer such as sodium chlorate.

The gravel can be 'all-in' material such as ballast or hoggin, or graded material such as river gravels and crushed rock (often $\frac{3}{4}$ in. to $\frac{1}{8}$ in. in size). It is normally laid in two layers, well watered and rolled to a total consolidated depth of about 6 in. to a crossfall of about 1 in 30.

GRASS VERGES

Grass verges possess great amenity value and also perform other functions such as absorption of sound and reduction of glare from headlamps of vehicles and street lights. They need designing with care to avoid excessively heavy wear and high maintenance costs. Narrow strips of grass between footpath and road kerb, sometimes down to 18 in. wide, are never really satisfactory and it would be far better to concentrate the grassed sections into a few larger landscaped areas at prominent points.

Grass verges are relatively cheap to establish, easy to reinstate but rather expensive to maintain, as they need about 12 cuts a year to ensure a reasonable appearance at all times. It is undesirable to lay verges to gradients in excess of 1 in 4 and a minimum desirable width is 4 ft 6 in. The finished surface should project about $\frac{3}{4}$ in. above adjoining surfaces such as kerbs, paving and manhole covers. It is also advisable to provide a 9 in. wide strip of gravel or ballast, treated with suitable weed

killer, between grassed areas and walls and to surround lamp columns, etc. with a 6-in. width of *in situ* concrete.

Prior to soiling and seeding, it is necessary to break up compacted surfaces and exposed subsoil, and where heavy clay is encountered it is advisable to provide a 4-in. layer of clinker or gravel for drainage purposes. The layer of soil should be at least 4 in. thick and cultivated so as to produce 2 in. of tilth, with a pH value of just over 5.0 obtained by the addition of hydrated lime.

A suitable fertiliser is generally distributed over the areas to be seeded at the rate of about $1\frac{1}{2}$ oz per yd^2 . The Ministry of Transport specify a fertiliser containing 10 per cent nitrogen, 15 per cent phosphoric acid and 10 per cent potash. Seeding is best performed in both directions at the rate of about $1\frac{1}{2}$ oz per yd^2 , the surface lightly harrowed to cover the seed and lightly rolled if the surface is dry.

The seed mixtures specified vary a great deal. For instance, the Ministry of Transport specify the following mix by weight for use on verges, central reserves and side slopes:

Perennial rye grass	60 lb
Red fescue	20 lb
Smooth stalked meadow grass	10 lb
Crested dogtail	12 lb
White clover	10 lb
	112 lb

The author used the next mentioned mix over a period of years for the seeding of verges and playing fields with good results. It may, however, be desirable to vary the mix according to the type of soil and location of the grassed area.

Short seeded perennial rye grass	60%
Chewings fescue	10%
Red fescue	10%
Agrostis Tenuis	10%
Crested dogtail	10%

Where a grassed area is needed immediately, a first-class job is required or there are practical difficulties with seeding, turfing is necessary. It is a more expensive treatment than seeding but can be carried out over a longer range of periods than seeding, which is generally restricted to spring and autumn. Turves vary in size but are often 2 ft by 1 ft or 3 ft by 1 ft and about $1\frac{1}{2}$ in. thick, and are laid from boards to

break bond over well-prepared soil. Turves should be watered after laying in dry periods.

There is a wide range of equipment available for grass cutting. In urban areas the 30 in. wide cylinder motor mower is the most popular for roadside verges, with an output of about 3,000 to 3,500 yd² per hr, whilst for larger areas a tractor-drawn gang mower—often of triple variety with a cutting width of 7 ft and output of 4 to 6 acres per hr is very effective.

In rural areas, cutting is often limited to about 3 times per year and reciprocating knife-action cutters are frequently used for this purpose. An alternative is to use grass growth retarders.

FOOTPATH CROSSINGS

It is often necessary to construct vehicular crossings across paths and verges to connect with house driveways and so prevent damage to the paths and verges. Single crossings are usually 8 ft wide and are generally constructed in concrete, about 4 in. thick, or tarmacadam or bitumen macadam, about 3 in. thick, on a suitable base of ballast, hoggin, clinker, etc.

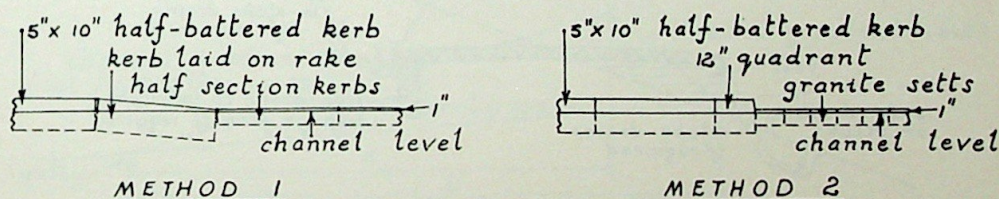


FIG. 27. Footpath crossings.

The junction of the crossing and the carriageway can be treated in a variety of different ways and the two most widely used methods will now be described.

One method is to use half-section kerbs or 10-in. deep kerbs laid on their sides, to project 1 in. above the finished surface of the carriageway. This enables vehicles to leave the carriageway reasonably smoothly and still provides an upstand to guide the flow of surface water. At each end of the crossing a standard kerb is laid on the rake to link up with the normal road kerbs as illustrated in Fig. 27.

Another method is to use granite setts in place of dropped kerbs, as they are more resistant to heavy wear and to provide a precast concrete quadrant at each end of the crossing, as illustrated in Fig. 27. It is

desirable to form a vertical curve in the surface of the crossing commencing at the back of the course of setts or dropped kerbs and extending over a length of about 15 in., so that the remainder of the crossing is at the same level as the adjoining path or verge. Another alternative occasionally adopted is to drop the footpath at each crossing, so that the crossing maintains an even longitudinal gradient, but this form of construction is most unsatisfactory for pedestrians, who face a constant series of 'ups and downs'.

ROAD DRAINAGE

Sub-soil Drainage

Water entering the subgrade can cause a substantial loss in strength in the soil foundation to a road. The water can reach the subgrade in three ways—surface water penetrating the pavement, water seeping through from higher ground adjacent to the road or a rise in water table level.

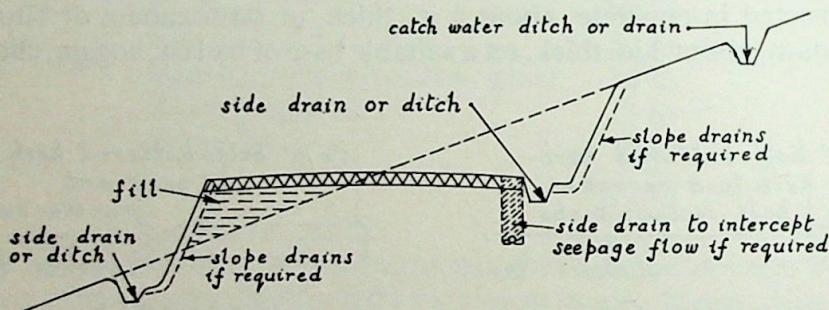


FIG. 28. Drainage on side slopes to roads.

The road formation should be kept a minimum of 4 ft above highest water level wherever possible. With permeable soils it is possible to reduce the water table level by installing longitudinal land drains on each side of the road, with the drain trenches filled with coarse sand or other selected filter media and sealed with clay at the top of the trench. On occasions a high water table overlies a thin impervious stratum, and the level of the water table can be lowered by penetrating the impervious stratum at intervals with vertical drains of coarse sand or other selected filter media.

In a well-designed road there is little fear of surface water penetrating the pavement, but there is often a real danger of surface water from adjoining higher land penetrating into the subgrade. This water must be intercepted in side drains or ditches as illustrated in Fig. 28.

With embankments it is customary to provide slope drains running down the slope to connect with a side drain or ditch at the side of the road. The slope drains are often constructed as French drains, consisting of trenches filled with pebbles or hardcore with the larger stones at the bottom and becoming progressively smaller towards the top of the trench. Ditches are generally about 4 ft wide at the top and 1 ft 6 in. at the bottom, and should have a minimum longitudinal gradient of 1 in 120. Land drains can be in a variety of materials—clayware field drains (B.S. 1196), perforated vitrified glazed ware, porous concrete (B.S. 1194) or perforated pitch fibre.

Surface and sub-soil water are rarely permitted to enter a foul sewerage system. In the few cases where it is permissible, reverse-action intercepting traps and trapped gullies with silt traps must be provided. Surface water systems usually drain into ditches and water-courses, but on occasions soakaways have to be used where there is no other practicable method. Soakaways must extend several feet into a permeable stratum and are best lined with perforated or porous concrete tubes or open jointed brickwork. Further information on the design of soakaways can be obtained from *Landscaping for Flats* (7).

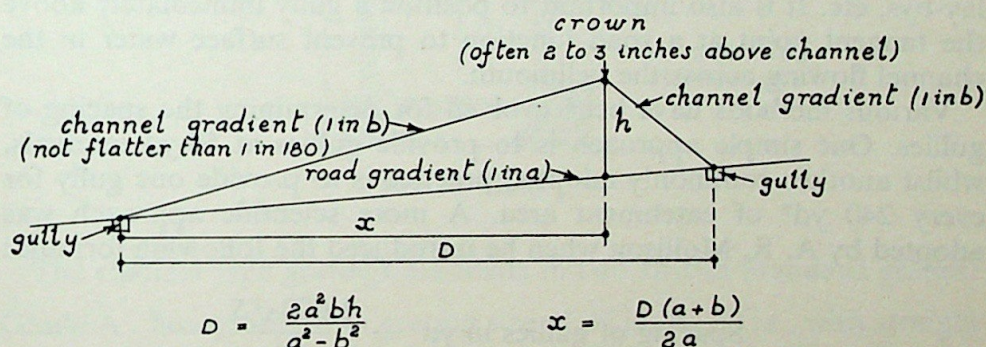


FIG. 29. Channel crowning.

Surface Water Drainage

Road surfaces are laid to specified cambers or straight crossfalls to shed the surface water to the channels. Minimum crossfalls vary with the form of construction—1 in 48 is generally suitable for relatively smooth surfaces such as asphalt or dense bitumen-macadam, whilst rougher surfaces such as open-textured macadam and concrete with a slightly corrugated surface are best finished to a crossfall of 1 in 36.

The minimum longitudinal gradient of a road should be 1 in 200 to ensure satisfactory surface water run-off, although roads laid to flatter

gradients can be drained satisfactorily by using channels carefully constructed in mastic asphalt or precast concrete sections, or by 'crowning' the channel between the gullies to provide steeper channel gradients than road gradients. The height of the crown in the channel above the road gradient is usually about 2 to 3 in. and the channel gradients should not be flatter than 1 in 180 (see Fig. 29). Readers requiring further information on this aspect are referred to the article by Hydes and Jacomb (8).

Roads in rural areas are often drained through trenches or 'grips', about 15 in. wide and 6 in. deep, leading across the grassed roadside areas to ditches. The motorways are mainly drained to French drains laid under the grass verges and central reservation.

Gullies

In urban areas the surface water run-off from highways is almost invariably discharged into gullies, which are usually trapped and are of sufficient capacity to retain a reasonable quantity of silt. Additional gullies are needed on gradients flatter than 1 in 200 or steeper than 1 in 20, on sag vertical curves, super-elevated lengths of road and at bus stops lay-bys, etc. It is also important to position a gully immediately above the tangent point at a road junction to prevent surface water in the channel flowing across the bellmouth.

Various methods have been evolved for determining the spacing of gullies. One simple approach is to provide gullies at 50-yd intervals, whilst another commonly adopted practice is to provide one gully for every 240 yd² of catchment area. A more scientific approach was adopted by A. R. Mollison when he introduced the following formula:

$$\text{Spacing of gullies in yd} = \frac{1,000\sqrt{S}}{W}$$

where S = gradient per cent (e.g. 1 in 50 = 2 per cent)

and W = width of paved area in ft (9).

Gully pots can be constructed in a number of different materials—precast concrete, glazed clayware, cast iron, steel, brickwork and *in situ* concrete. For normal requirements both the precast concrete (B.S. 556) and clayware (B.S. 539) pots are entirely satisfactory. They can be trapped or untrapped and supplied with or without rodding eyes, in a variety of sizes ranging from 15 in. diameter and 30 in. deep to 24 in. diameter and 42 in. deep with precast concrete pots; and from 12 in. diameter and 24 in. deep to 18 in. diameter and 36 in. deep (a

commonly used size) with clayware pots. The outlets are usually of 6 in. diameter, and a typical gully pot is illustrated in Fig. 30.

The gully gratings through which the surface water enters the pot are of two main forms—channel and kerb inlet; in cast iron, cast steel or a mixture of both (see B.S. 497).

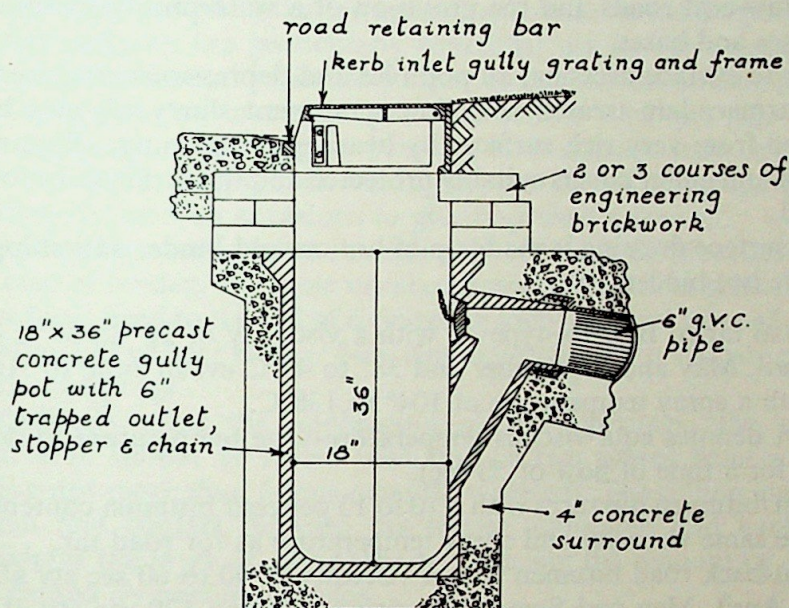


FIG. 30. Gully pot.

The channel type gratings are made in two British Standard grades:

- Grade A: heavy duty with grating size of 20 in. by 20 in., with straight bars at an angle of 45° to kerb forming a double triangular gully grating for use on main roads.
- Grade B: medium duty with grating size of 16 in. by 14 in. or 20 in. by 14 in., with straight bars set at 90° to the kerb for gradients flatter than 1 in 50, or with curved bars set at 45° to the kerb for gradients of 1 in 50 or over, for use on secondary roads.

The kerb inlet type are only really suitable for light duty but have a number of advantages—they eliminate obstructions in the carriageway, facilitate road construction and resurfacing and there is less risk of blockage. On the other hand they obstruct a section of the path or verge and need anti-deflector plates in the channel where the gradient exceeds 1 in 50.

SURFACE DRESSING

Surface dressing is applied periodically to flexible road surfacings to provide a non-skid wearing surface and an impervious sealing coat. It also prevents disintegration of the road structure and can be used to give contrasting colour and texture. Further uses include the strengthening of low-cost roads and the provision of a waterproof membrane to sub-bases and bases.

Prior to surface dressing, all potholes and depressions must be filled, fresh tarmacadam treated with lime or cement slurry, surplus binder removed from very rich surfaces by heating and planing, all manhole, hydrant and gulley covers suitably protected and the surfaces thoroughly cleaned.

The surface dressing is made up of hot or cold binder and chippings. Suitable hot binders are:

- (1) Road tar to B.S. 76, type A, with a viscosity of 34° to 38°C evt in April, May and September and 38° to 42°C evt in June to August, with a spray temperature of 104° to 138°C.
(evt denotes equi-viscous temperature—the temperature in degrees C for a time of flow of 50 sec).
- (2) Tar/bitumen mixtures with a 10 to 15 per cent bitumen content with the same viscosity and spray temperature as for road tar.
- (3) Cut-back road bitumen with a viscosity of 40 to 60 sec stv at 40°C in April, May and September, rising to 80 to 120 sec stv at 40°C in June to August and a spray temperature of 138° to 160°C.
(stv denotes standard tar viscometer—the time of flow in seconds measured at 40°C.)

Rubberised binders with a rubber content of about 0.4 per cent have been used to reduce bleeding and give improved adhesion. High-viscosity binders are also useful when extra binder is needed to hold chippings in place.

These binders are normally distributed mechanically from distributors operating on the gravity head or constant pressure principle, with capacities up to 2,500 gals. The rate of spread with constant pressure distributors is linked with the road speed.

For very small areas portable boilers, buckets and stiff brooms or rubber squeegees may be used, with a hand sprayer for rather larger areas.

The rate of spread of binder depends on many factors—the size and type of chipping, type of binder, intensity of traffic carried and nature of surface to be dressed. As a rough guide, using $\frac{1}{2}$ -in. chippings under

average conditions the rate of spread of tar would be about $3\frac{1}{2}$ to 5 yd² per gal, and bitumen would be about $4\frac{1}{2}$ to 6 yd² per gallon. A small proportion of adhesion agent may be added to the binder to prevent the displacement of chippings in wet weather.

Cold binders consist of emulsions which are globules of bitumen dispersed in water by the addition of surface-active agents. The two main types are anionic (alkaline agents) and cationic (acid agents), and the latter category are particularly suited for use in wet weather. The method of distribution is similar to that of hot binders and an average rate of spread with $\frac{1}{2}$ -in. chippings would be 3 to 4 yd² per gal.

The chippings used vary from $\frac{1}{8}$ in. to $\frac{3}{4}$ in. in size and may be granite, basalt, limestone, slag, gravel, etc. Lightly pre-coated chippings and hot chippings are used on occasions to give improved adhesion.

The chippings are applied immediately after the distribution of the spray coat of binder. The most usual equipment is a trailer gritter with a hopper feed, fixed to the tail of a reversing lorry. Typical rates of spread are 100 to 120 yd² per ton for $\frac{3}{8}$ -in. chippings and 80 to 100 yd² per ton for $\frac{1}{2}$ -in. chippings.

Immediately after the application of the chippings, the surface dressed area should be rolled with one or two passes from a roller weighing not more than 6 tons (smooth-wheeled). The rolling increases adhesion and contact between the binder, chippings and base, and consolidates the layer of stone thereby reducing the amount of disturbance caused by passing vehicles.

The best time for surface dressing is usually April to June, and it is advisable to stockpile chippings in advance of the work to avoid any possibility of hold-ups on the job. Comprehensive records should be kept of the location of each day's work and the conditions of working. Under average conditions an output of 2,000 gal per day can be achieved with fully mechanised equipment.

For further information on surface dressing the reader is referred to the publications listed under reference (10) at the end of this chapter.

SNOW CLEARANCE

Snow clearing from highways can be one of the most important and exacting functions undertaken by the municipal engineer during the winter months, in order to keep all roads open to traffic as far as practicable. The essential basic requirement of this class of work is good planning and organisation, although the actual details will vary with the type of authority and the particular characteristics of the area.

It is essential that adequate stocks of salt and abrasives are built-up by July and that all necessary snow clearing equipment is available for action and maintained in good working order. Close contact with the nearest meteorological centre or aerodrome must be maintained, so that advance information of possible snowfalls is obtained. A list of priorities must be prepared and the gangs of men well briefed as to their respective courses of action. Furthermore, arrangements must be made with local farmers, plant-hire firms and civil engineering contractors working in the area of the authority to perform specific functions, mainly with their own plant, in the event of snowfalls exceeding 2 in. in depth.

In some localities the drifting of snow can be controlled by the erection in the autumn of snow fencing, usually made up of 4-ft high chestnut pale fencing fixed to timber posts at 9-ft centres, with the bottom of the fencing finishing about 6 in. above ground. This fencing is erected vertically and at right angles to the prevailing snow-bearing wind, about 70 ft from the highway boundary.

In the case of a county it is advisable to set up a central control room manned 24 hours a day during periods of snow, coupled to the divisions and selected plant by a short-wave radio system, as described by A. H. Kennard (11).

A variety of snow clearing equipment is normally used and workmen from other sections of the local authority's labour force such as refuse collectors and gardeners take part. Snow plough blades are fitted to all types of vehicle from graders to maintenance tractors and lorries. The best type of snow plough blade is generally considered to be the straight-bladed type capable of being angled in either direction and mounted on independent frames.

The best form of gritter is probably that where the abrasive and salt is fed through an aperture in the floor of the lorry on to a spinner which is fitted in front of the rear driving wheels. This dispenses with the dangers associated with throwing material over a lorry tailboard into the hopper of a trailer type gritter.

Snow blowers are now being used to an increasing extent and do a splendid job in deep drifts. In Kent one such machine cleared 3 miles of snow 6 ft deep in a 10-hour day.

In recent years a number of local authorities have used salt, in preference to a mixture of salt and abrasive in the proportions of about 1:4 (the abrasive normally being $\frac{3}{8}$ in. or $\frac{1}{4}$ in. single-sized aggregate or $\frac{3}{8}$ in. sand), during and after falls of snow. Where the snow exceeds 2 in. in depth, it is advisable to use a snow plough followed by the application of salt (12). Salt melts ice at temperatures below 32°F (0°C).

The advantages of using salt are that it does not have to be swept up

subsequently, it does not clog gullies and sewers, it cannot cause damage by being thrown up by passing vehicles, it prevents snow freezing to road surfaces and clogging ploughs and blowers, and generally eases the task of removing the snow and avoids the formation of ruts of packed frozen snow. On the other hand vehicles must be emptied and washed on return to the depot and a succession of applications can cause damage to road surfacings.

The best salt to use is rock salt complying with B.S. 3247, and rock salt No. 4 can be stored for long periods without appreciable deterioration. The following rates of spread have been found to be effective in Kent.

- (1) Pre-salting to prevent icing: $\frac{1}{2}$ oz per yd².
- (2) Continuous salting during snow in falling temperatures: 1 oz per yd².
- (3) Speedy action on snow already laying: 2 to 3 oz per yd².

In towns it is not usual to have short-wave radio facilities available for communication, and at Hastings arrangements were made with the G.P.O. whereby all telephone boxes could be used as reporting points (11).

In Tonbridge sandbags filled with ground rock salt were located at points throughout the district, where past experience had shown that speedy application was most needed. These points ranged from exposed parts of steep hills on Class 'A' roads to small flights of steps and public footpaths in the town centre. Considerable improvisation was effected at Tonbridge with the use of an Allen auto-scythe with small blade attachment for clearing footpaths, and a small iron plough fitted to a long handle with a 'D' head for clearing channels, so that melting snow and ice was able to flow to the gullies (11).

Snow clearing operations must be treated as an emergency and a team effort is needed with maximum co-operation and goodwill shown by all concerned. The supply of hot drinks by the catering department at Hastings to men working through the night on snow clearing work must have helped to promote maximum output.

STREET LIGHTING

Street lighting installations can be subdivided into two main categories.

- (1) Those serving traffic routes
- (2) Those serving other roads requiring lighting, being mainly residential roads.

The method of lighting must have regard to the traffic importance of the road, the type of area through which it passes, the properties of carriageway surface and existence or otherwise of humps, bends, overhanging trees, etc., as well as initial capital and running costs.

The Code of Practice on *Street Lighting* (13) classifies lighting for streets into a number of groups:

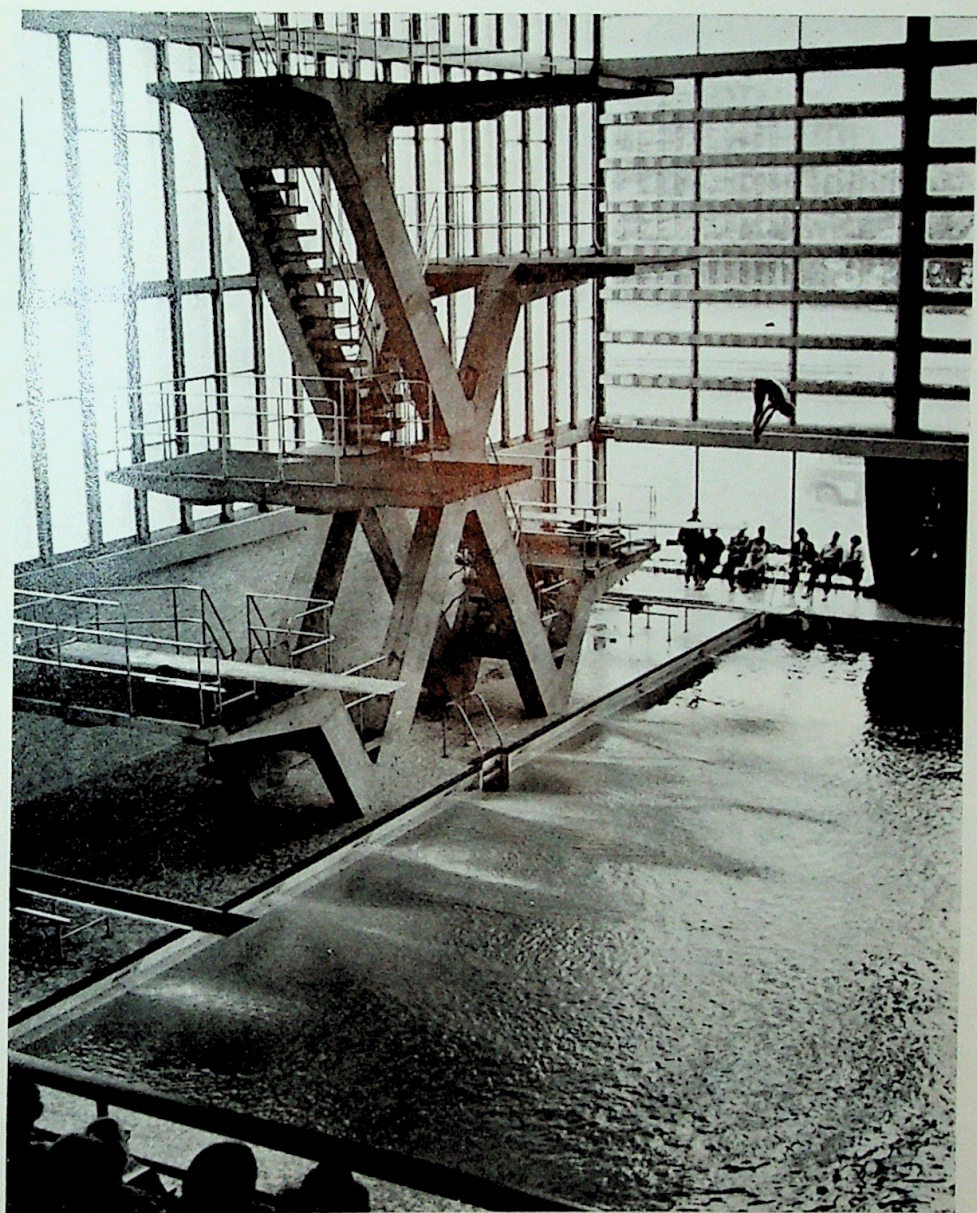
- | | |
|---------------|---|
| Group A1 | principal traffic routes. |
| Group A2 | normal traffic routes (main roads having considerable vehicular and pedestrian traffic). |
| Group A3 | minor traffic routes (main rural roads or minor urban roads carrying traffic which is not confined to the immediate locality, but which does not need Group A2 lighting). |
| Group B | roads carrying only local traffic (e.g. residential and unclassified roads). |
| Groups C to G | cover roundabouts and complex junctions, bridges and flyovers, tunnels and underpasses, roads with special requirements, and town and city centres. |

The main aims of street lighting are to reveal all features of the street and traffic which are important to all users. The lighting installations should be of pleasing appearance by night and by day and their lighting effect on buildings should not be displeasing. Kerbs, vehicles and pedestrians must stand out in clear contrast to their surroundings, whilst the carriageway surface must appear bright and fairly uniform.

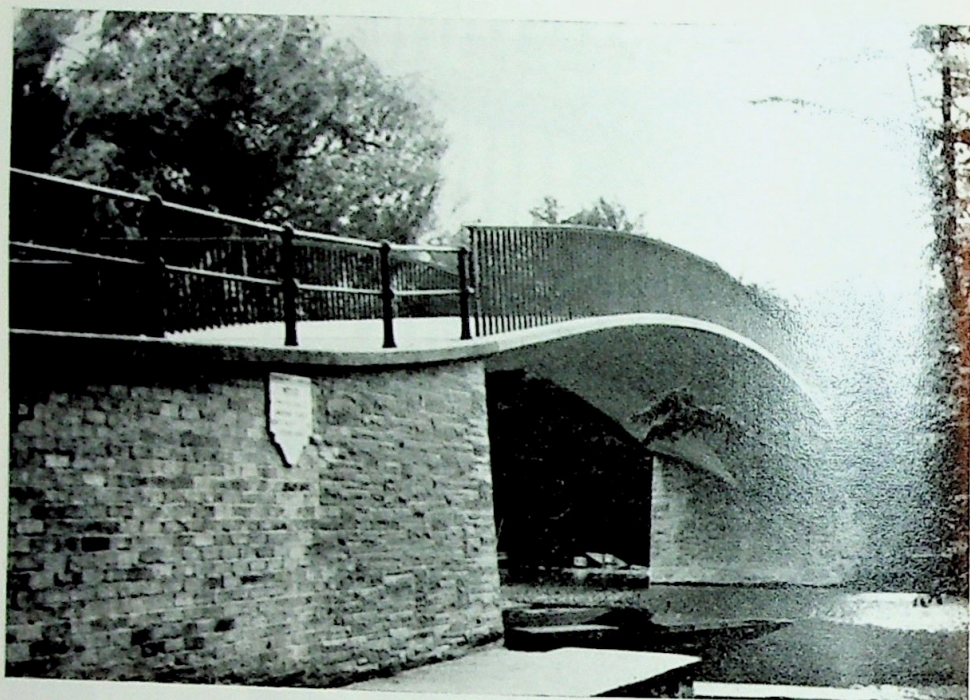
Glare is caused by light leaving the lanterns between the horizontal and about 20° below it. Glare is reduced by light road surfaces and light coloured buildings beside the road.

The height of columns and lanterns should not exceed that of the eaves of adjoining buildings to secure satisfactory aesthetic conditions. Wall brackets are usually preferable to lamp columns. Brackets should be limited in length and straight raking brackets are favoured in the Code of Practice (13). Both columns and brackets should be as slender and unobtrusive as possible and steel and aluminium columns often offer a better appearance than concrete columns, but are more costly in maintenance. A wide variety of concrete columns and brackets are available to designs approved by the Royal Fine Arts Commission, and a number of coloured concrete columns are in use (see B.S. 1308 and 1840).

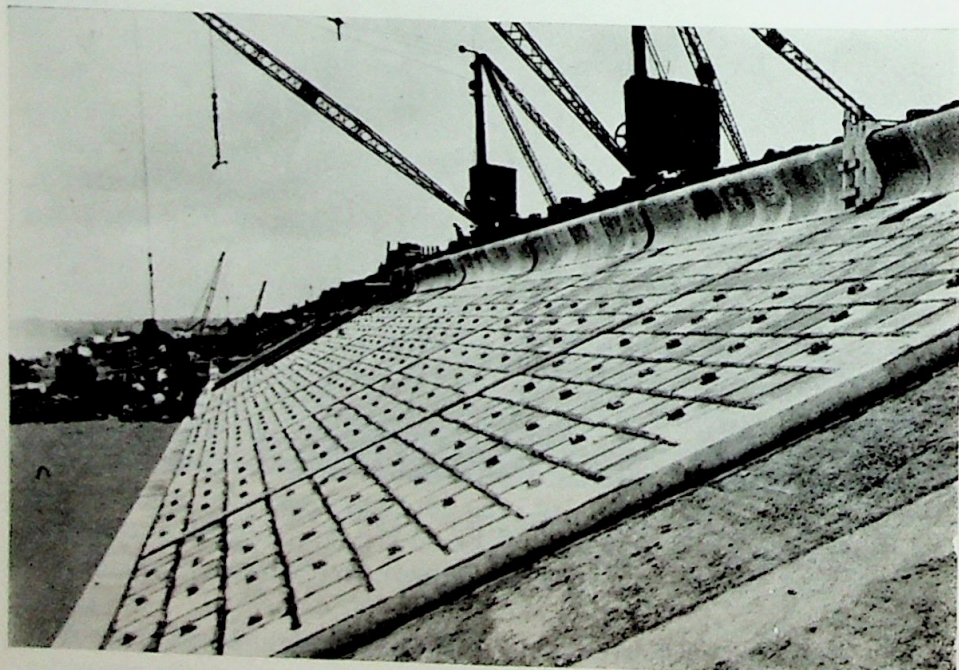
When siting columns, care should be taken to ensure that they do not adversely affect views of outstanding buildings or entail drastic cutting



I Diving Board at Crystal Palace



II Garret Hostel Bridge, Cambridge



III Sea Wall, Aberdeen

back of trees. In new streets it is advisable to fix the positions of the lighting columns before preparing a tree planting scheme. Columns should be sited at least 5 ft from the carriageway where this can be done without obstructing the footway or involving an excessive length of bracket. Mounting heights of lanterns for traffic routes should be 25, 30, 35 or 40 ft.

Lighting Systems

There are two main types of lighting system.

(1) **Cut-off.** In this system there is a rapid reduction in the luminous intensity between about 80° and the horizontal. This arrangement reduces glare but it results in a small and nearly uniform spacing/height ratio, and operates better with the more matt carriageway surfaces, large trees, long straight lengths of road and an absence of buildings.

In the staggered cut-off system, the maximum spacing ranges between 3 times the mounting height for Group A1 lighting to 3.4 times the mounting height for Group A3 lighting, whilst the minimum light flux per lantern in the lower hemisphere (in lumens) varies from $8 \times (\text{mounting height})^2$ to $6 \times (\text{mounting height})^2$.

(2) **Semi-cut-off.** In this system there is a less severe reduction in luminous intensity between 80° and the horizontal. This arrangement gives a greater flexibility in siting but increases the liability to produce glare. It is better suited for use with smooth carriageway surfaces, where there are buildings alongside the road, staggered arrangements and numerous road intersections.

With the staggered semi-cut-off system the spacing ranges from $4 \times$ mounting height for Group A1 lighting to $4.8 \times$ mounting height for Group A3 lighting, whilst the minimum light flux per lantern in the lower hemisphere varies from $10 \times (\text{mounting height})^2$ to $6 \times (\text{mounting height})^2$.

In the Code of Practice there are sets of tables covering mounting heights, widths between alternate columns, maximum spacing, minimum light flux per lantern and maximum overhang under both systems for a variety of different siting arrangements. These arrangements include staggered, opposite, opposite plus central, central and single side. Road junctions and bends require special consideration in all cases.

Thus the spacing of the lighting columns is largely dependent on the mounting height adopted. With residential roads a staggered formation is generally preferred.

Types of Lamps

There are four main types of lamp available for street lighting purposes and a large variety of lanterns.

(1) **Tungsten Filament (B.S. 161).** This is a low-cost lamp with relatively low efficiency and a short life. It has a warm white colour and does not require control gear but is subject to rapid failure. 100 to 200-W lamps are used in residential streets.

(2) **Tubular Fluorescent (B.S. 1853).** This is available in various colours, although the cool white (daylight) type is generally used for street lighting purposes. It has a high efficiency and a long life but needs control gear and is relatively expensive in first cost. The sizes most frequently used for street lighting purposes are 20-W (2 ft), 40-W (2 ft and 4 ft) and 80-W (5 ft).

(3) **Mercury Discharge.** The characteristic blue/green light of previous mercury discharge lamps is now being improved by the fluorescent coated type which adds a proportion of red light. This lamp has a long life with high efficiency.

(4) **Sodium Discharge.** The yellow colouring is not universally favoured although this lamp operates very efficiently in fog and reduces glare. It often has to be fixed horizontally and has a long life. 60-W lamps are frequently used on residential roads.

A useful paper on the relationship of highway lighting to road accidents is listed in reference 14.

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CHAPTER FOUR

Building and Civil Engineering Construction

THE municipal engineer is very much concerned with building and civil engineering constructional methods, as they form an important part of much of the work for which he is responsible. He is often required to design and supervise the constructional work, but in some cases he may be responsible, with the assistance of building inspectors or surveyors, for checking and approving the designs submitted by others under building regulations.

The constructional work includes temporary work such as shoring, cofferdams, etc. which will be needed in order that the permanent constructional work may proceed. This chapter is subdivided into the main classes of constructional work according to the materials used or function of the structure.

In building work each element of the structure has to perform a number of functions, e.g. external walls may be load-bearing, and will have to be weather-resistant, durable, of pleasing appearance, have good thermal insulation properties, be reasonably economical in both constructional and maintenance costs, etc. This aspect of building construction is dealt with very fully in two Government publications entitled *Principles of Modern Building* (see reference 1 at the end of this chapter).

TIMBER STRUCTURES

Timber is used extensively in domestic construction, as well as in frameworks to industrial buildings, sports pavilions, bus shelters and other public erections, and also for piling work alongside rivers and on the

coast and in trench timbering, shoring and other temporary work. There seems little doubt that timber will also have an important part to play in industrialised building.

There are many species of timber and these vary considerably in their properties. Hence it is necessary to be able to accurately identify the different species of timber, and this is usually based on differences in anatomical structure. Considerable emphasis is now given to the need for treating building timbers against attack by wood-boring insects and wood-destroying fungi. Great importance is also attached to the adequate seasoning of timber to reduce the moisture content down to certain specified limits. For instance, it is advisable in flooring over sub-floor heating elements to have a moisture content not exceeding 8 to 9 per cent.

From the structural viewpoint, the municipal engineer is very much concerned with the safe working stresses of timber, methods of jointing and the performance of timber structures. Timber is graded according to the extent of defects, such as knot size, slope of grain, etc. It is often found that the weakest link is the joint between adjacent members, and the method of jointing varies between nails, screws, bolts, timber connectors and adhesives. Much valuable guidance can be obtained from the relevant Code of Practice (2).

In an attempt to reduce site labour costs and speed-up construction, trussed rafters are now being used extensively in house construction. They can be fabricated using no more timber than a traditional rafter/purlin type of roof, and, as they span between external walls, they permit greater freedom in the planning of rooms and the use of lighter partitions which no longer need to provide roof support. Two main types of trussed rafter are in use: (1) a folding type of truss using bolts, shear plates or split-ring connectors, which is particularly suitable for large spans and roof pitches over 30°; (2) non-folding plywood gusset plated or light metal jointing plated type which is well suited for lower pitches and has the advantage of simpler fabrication and adaptability to mechanised construction.

Composite wood products are being used to an ever-increasing extent, particularly in the form of panels such as plywood and wood chipboard, but also in structural laminated beams, columns and trusses. These latter members have considerable structural strength and a relatively high fire resistance. Furthermore, there is no need for protection against corrosion.

The Forest Products Research Laboratory, at Princes Risborough in Buckinghamshire, undertakes a vast amount of research with the object of promoting the most economical use of timber (3). Its services are

readily available to municipal engineers for dealing with timber queries.

Commonly adopted maximum stresses for timber are listed in Table 5. Furthermore, the maximum deflection under proper loading must not exceed $\frac{1}{360} \times$ its length or span.

TABLE 5

<i>Nature of stress</i>	<i>Max. stress in lb/in²</i>	
	<i>Non-graded timber</i>	<i>Graded timber</i>
Extreme fibre stress in bending	800	1200
Shear stress in direction of grain	90	100
Compression perpendicular to grain	165	325
Tension in direction of grain	800	1000
Compression in direction of grain for struts where slenderness ratio does not exceed 10	800	1200
Modulus of elasticity	12×10^5	16×10^5

BRICKWORK

Brickwork plays an important part in the majority of municipal engineering projects, in the form of commons, engineering and facing bricks.

The strength of common bricks ranges from 1,500 to 7,000 lb/in². The strength of the brickwork depends on the strength of the bricks and the associated mortar and can be determined by reference to B.S. Code of Practice 111 (4). In flat construction, where the load-carrying brickwork is adequately stiffened or restrained by intersecting floors and walls, considerable economy can often be achieved by the omission of a structural steel or concrete frame for part of the structure (5).

In addition brickwork, particularly in cavity wall construction, has good sound and thermal insulation properties. There is a vast range of facing bricks available in a wide variety of colours and textures which are well illustrated in the Brick Bulletins (6), and the use of these bricks can do much to improve the character and appearance of many municipal engineering projects such as housing schemes, schools and public buildings of all kinds. Engineering bricks to B.S. 3921 are frequently used in manhole construction, sewage disposal works and work where great strength and durability are required.

STEEL FRAMEWORKS

Steel frameworks are used for a variety of building projects, from schools and colleges to multi-storey office blocks, flats and hotels. New trends in design such as the plastic design theory, composite construction of steel and concrete, the use of high strength friction grip bolts, Universal beams and columns with greater strength for less weight of steel, high yield stress steel and the application of computer analyses, have all led to more efficient methods and a lowering of constructional costs.

Steel also lends itself well to use in industrialised building systems and it has a tremendous strength to weight ratio. Steelwork is speedily erected and extremely adaptable with a variety of jointing methods—welded, bolted or riveted.

The introduction of Universal sections has resulted in many advantages:

- (1) These members are more efficient on a strength/weight basis.
- (2) Many of the beams are rolled thus permitting the use of simple sections.
- (3) Columns are available which will carry 1,000 ton in mild steel or 1,400 ton in high-yield-stress steel on an effective length of 10 ft.
- (4) Several weights are available in each size making for greater efficiency.
- (5) Simplified sections and fabrication processes have been introduced.

The ultimate strength of mild steel is 28 to 33 ton/in² and the minimum yield stress is 16 ton/in² (B.S. 15). High-yield-stress steel has a yield stress of 22 to 23 ton/in² (B.S. 968), giving a much increased strength at relatively little extra cost.

Steelwork is designed in accordance with B.S. 449 (7), which is revised at about yearly intervals, and this covers the use of semi-rigid and rigid (elastic and plastic) methods of design. Site riveting has now been replaced almost entirely by the use of high-strength, friction-grip bolts or welding. These bolts greatly reduce the amount of labour required for jointing and eliminate the need for skilled operatives for jointing purposes.

The loads of steel stanchions are normally spread over a sufficient area of ground by means of steel grillages or bloom bases on reinforced concrete pads. Steelwork which is to be left exposed requires protection against corrosion, usually by painting or metallising. Furthermore, building regulations often require steelwork to be protected against fire and, in the past, this has often been done by encasing the steel

members in concrete. This process has several disadvantages, including slowing down the constructional work and increasing the weights to be carried by the steelwork and foundations. These disadvantages can be overcome by the use of prefabricated lightweight casings, many of which are illustrated in a British Construction Steelwork Association publication (8).

Steel frames are largely fabricated away from the site, resulting in speedier construction, and it is the lightest form of construction available. Its multiplicity of uses, to buildings of all types and shapes, is well illustrated in the booklets—*Building with Steel* (9). Finally, its use in industrialised building cannot be disputed, assisting in the use of dimensional co-ordination and providing ease of attachment of pre-formed cladding units.

REINFORCED CONCRETE CONSTRUCTION

A wide variety of buildings are constructed with reinforced concrete frameworks and this form of construction is almost universally employed for sewage disposal works tanks, water towers and road bridges. The wide range and graceful appearance of some of these structures is well illustrated in *Concrete Quarterly* (10).

High standards of design and construction are required in this class of work. Designs of reinforced concrete structures are normally carried out in accordance with Code of Practice 114 (11), and those for buildings of prestressed concrete in accordance with Code of Practice 115 (12).

Concrete can be made from a variety of aggregates, of which the ones mainly used in this country are naturally-occurring gravels and sands, crushed rock and blast-furnace slag. The strength of the concrete will be largely influenced by the grading and proportions of the aggregates and the water/cement ratio, which is usually about 0.50.

In reinforced concrete construction advantage is taken of the high strength of concrete in compression and of the steel bars in tension. Hence when a reinforced concrete member is stretched, both concrete and steel reinforcement will receive the same strain, but the steel bars will receive about 15 times the stress in the concrete (modular ratio).

The concrete is supported by formwork which must be sufficiently strong to retain the concrete without the slightest movement and is often required to produce a relatively smooth face to the concrete. The length of time during which the formwork has to remain in position after the concrete is poured and vibrated varies from about 2 to 28 days, depending on the type of member, weather conditions and type of cement used.

A sketch showing shuttering or formwork to a reinforced concrete column is shown in Fig. 31.

Concrete can be mixed on the job or purchased ready-mixed, when it will be delivered to the site, exactly as specified, in lorries with revolving containers to prevent the coarse aggregate settling at the bottom of the concrete. In certain circumstances the latter form of concrete may prove the most satisfactory and economical.

The principal types of reinforcement used are rolled steel bars to B.S. 785, cold twisted steel bars to B.S. 1144 and steel fabric to B.S. 1221. The reinforcement is rigidly tied at intersections with 16 s.w.g. soft iron wire to provide the correct amount of concrete cover.

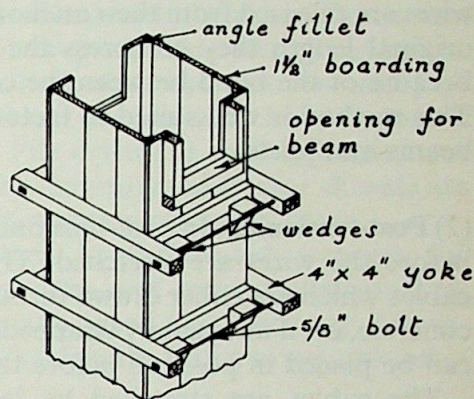


FIG. 31. Shuttering to reinforced concrete column.

Prestressed Concrete

In recent years, prestressed concrete has been used extensively in building and civil engineering work, and particularly in the construction of bridges. Its main advantages are the use of smaller and lighter sections, often precast, and the use of reinforced concrete members for longer spans.

With a normal reinforced concrete beam the steel reinforcement stretches as it takes up the tension and the concrete may crack in the process. In prestressing the concrete is compressed to such an extent that, when it is in use under a load, either there will be no tension at all in the concrete or it will be so little that no cracks will form.

The steel used for prestressing is usually made up of hard drawn steel wires up to $\frac{1}{4}$ in. diameter with an ultimate tensile stress of between 100 and 150 ton/in². The weight of steel in a prestressed concrete beam is usually about one quarter of that needed in a normal reinforced concrete beam and there will also be less concrete.

There are two principal methods of prestressing concrete:

(1) **Pre-tensioning.** In pre-tensioning, steel wires are stretched very tightly between fixed abutments and are anchored securely to them.

Concrete is then poured into moulds assembled around the stretched wires, and when the concrete has attained the necessary strength, the wires are released from their anchorages. In attempting to return to their original length they compress the concrete, and the wires cannot slip because of the bond between the concrete and the surface of the wires. This method is well suited to factory production of units, such as small beams and joists.

(2) **Post-tensioning.** In post-tensioning the concrete is permitted to harden before the wires are stretched. The wires are normally made up into cables which are either drawn through holes specially left for them in the concrete, or, if adequately wrapped to prevent bonding with the concrete can be placed in position before the concrete is poured.

The cables are stretched by jacks acting against the ends of the hardened concrete and they are permanently anchored by special cones or wedges before the jacks are released. Cement grout is usually injected under pressure into the cable cavity to protect the wires from corrosion. This method is well suited for making large span units.

Reinforced concrete members generally are attractive in appearance and require little maintenance. Precast concrete frames are used extensively for factory buildings, because they are economical in construction, capable of speedy erection, flexible, of good appearance, provide clear spans of from 20 to 100 ft and have low maintenance costs. There are many choices of roof design, ranging from the symmetrical shell roof and the northlight to the sharp curve and single arch vaults.

Plates I and II illustrate the use of prestressed concrete in a footbridge and in a diving board. The bridge was built in 1960 with a clear span of 80 ft and a width of 14 ft. It consists of a hinged portal frame of reinforced concrete supported by cased concrete raking piles. The transom is of winged cross section prestressed by longitudinal post-tensioned cables and incorporates twin plastic water mains at the neutral layer. The soffit is tooled to expose the Cornish granite aggregate and the deck is paved with York stone. The diving board is at the Crystal Palace sports centre, London.

PLANT DEVELOPMENT

More and larger items of plant are now being employed on building and civil engineering sites. Due to the high operating costs of this plant the

majority of jobs are, in consequence, much more carefully planned to ensure maximum utilisation of the plant.

Demolition work can often be carried out with the use of flameproof methods where explosives would not be permitted. Strip foundations can be satisfactorily excavated with a back-acter excavator mounted on the rear of a tractor and many of these tractors also have hydraulic loading shovels on their front ends. Pile driving is mainly carried out with the use of diesel hammers and crawler mounted tractor shovels are used extensively for excavation and demolition clearance work.

On large jobs one frequently finds hand-operated scrapers for loading mixers, built-in hydraulic weighers and cement silos used at concrete mixing points, to give maximum speed and efficiency. Mono-rail transporters enable concrete to be readily transported around a site.

Tower cranes are now installed on the site of every large building for handling of materials. They are of three main types.

- (1) Cranes which travel along a curved or straight track.
- (2) Those which are designed to stand beside a building under construction mounted on a fixed base (sometimes located in a courtyard, lift shaft or stairwell).
- (3) Cranes which commence by being mounted on a fixed base and which are later hoisted up the building as the work proceeds (climbing cranes).

PILING

Where the subsoil on a building site has insufficient load-bearing capacity, it may be necessary to drive a number of piles to support the foundations to the building. Piles can be classified into two main categories.

- (1) Bearing piles—where the piles are driven into a firm stratum which carries the loads transmitted by the piles.
- (2) Friction piles—where a firm stratum is at an excessive depth and the piles are supported by the friction of the earth against the sides of the piles.

Piles may be of timber, steel, or reinforced concrete, although the latter material is usually the most suitable for those used on building sites.

Timber piles are often used for river and sea defence work and are best made of greenheart to give maximum resistance to wood borers. A cast iron shoe is attached to the bottom of the pile and a steel ring is fixed to the top to prevent splitting of the timber during driving.

Steel piles are mainly of the screw variety with a solid mild steel shaft of about 3 in. to 8 in. diameter. These piles are rotated and not driven and thereby cause less vibration.

Reinforced concrete piles are particularly useful in that they are less likely to deteriorate under most conditions, can be made in a variety of sizes and lengths and can be connected into the structure of the building. They are of two main types:

Precast Concrete Piles

These are very popular as they can be obtained fully matured. On the other hand, they must be carefully handled and driven to avoid damage and additional reinforcement is often introduced as a safeguard. The actual length of pile required may not always be the same as the test pile; if a shorter length is required part of the pile will be wasted and if a longer length is required, then a further costly and not entirely satisfactory operation is needed. A typical precast reinforced concrete pile is illustrated in Fig. 32.

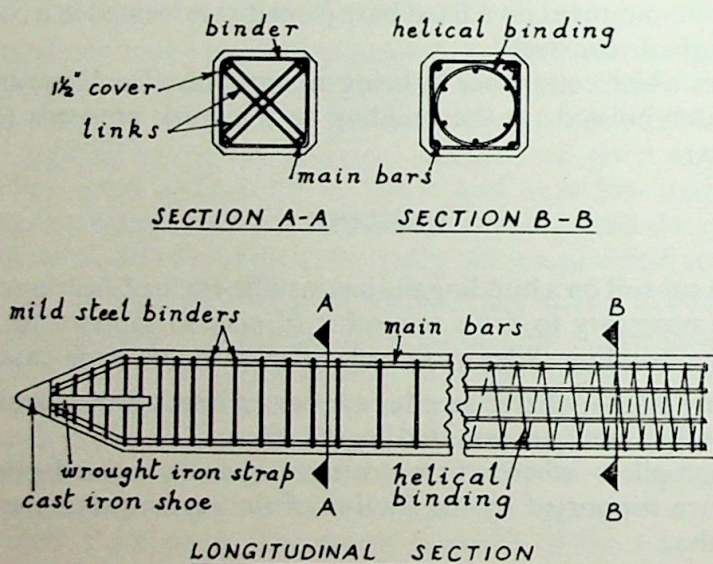


FIG. 32. Precast reinforced concrete pile.

'In situ' Concrete Piles

This type of pile can take several forms and the main advantages are that it does not require handling or driving, is always of the correct length and there is no need to provide additional reinforcement. On the

other hand, the concrete takes times to mature and the quality, placing and vibrating of the concrete cannot be controlled so rigidly.

In one type of *in situ* pile, the hole is formed in the ground by driving a tube with a pointed shoe, reinforcement is placed in position if required and the void filled with concrete as the tube is withdrawn.

With another system the shell or casing is left in position and filled with concrete, reinforced if necessary. Different methods use varying types of casing. The main advantages are that the casings are driven until a satisfactory set (amount of penetration for a given blow) is obtained and there will be no disturbance due to removal of the casing.

Yet another system uses a heavy lining and auger as for boreholes. The auger is removed, compressed air admitted and cement grout forced into the surrounding soil to form a mushroom base. Concrete is then introduced as the lining is withdrawn.

Pile Driving

Piles are usually driven by diesel hammers. The loading capacity of a driven pile will depend on the resistance offered by the stratum into which the pile penetrates, the frictional resistance of the strata at the sides of the pile and the strength of the pile itself.

The following approximate formula can be used to determine the safe load that can be supported by a pile (see also Hiley formula on page 48).

$$\text{Safe load in cwt} = \frac{Wh}{8d}$$

where W = weight of hammer in cwt

h = height fallen by hammer in inches

d = distance driven by last blow in inches

Steel Sheet Piling

Steel sheet piling is made up of a series of interlocking steel sections, made in various forms, which together form a continuous barrier. They can be used to form river walls and wharves, or be positioned at the base of sea walls and as cofferdam walls, etc. to exclude water from constructional works which are below

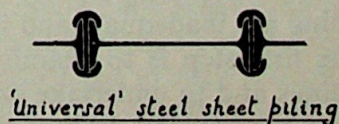
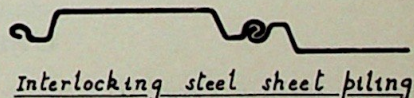


FIG. 33. Steel sheet piling.

water level. A typical section of steel sheet piling is illustrated in Fig. 33.

FOUNDATIONS

Normal domestic foundations are in the form of concrete strips about 24 in. $\times$ 9 in. in section at a depth of about 2 ft below ground level. The actual width will vary with the load-bearing capacity of the soil, which varies from 2 ton/ft² or less with very soft clay and silt up to 4 to 6 ton/ft² with compact gravel or sand-gravel mixtures. Wide strip foundations incorporating longitudinal and transverse reinforcement may be needed on weak soils. Pad foundations will be used under stanchion bases or piers.

On shrinkable clay soils, where the clay shrinks in dry weather and swells under wet conditions, the best solution is probably to construct narrow strip or deep beam concrete foundations, 15 in. wide by a minimum of 3 ft 6 in. deep under external walls and 2 ft deep under internal walls.

Another solution on sites of shrinkable clay would be to use short-bored piles of about 12 in. diameter and 8 to 10 ft deep. The average spacing of these piles is about 8 ft, with the exact location determined by door and window openings, as it is usual to position a pile on each side of every opening and two piles at each corner of the building and under chimney breasts. A lightly reinforced concrete beam about 12 in. wide $\times$ 6 in. deep spans between the piles and is anchored to them.

With made-up ground or fill, it is usually advisable to use a concrete raft foundation, reinforced at top and bottom, to carry light structures, such as houses. With loose or deep fills, particularly those supporting heavy structures, it is preferable to use pile and beam foundations.

UNDERPINNING

Underpinning is necessary where building work is to be carried out below existing walls. Typical instances may be when it is necessary to construct a basement adjoining a party wall, or where the existing foundations to a building are inadequate and it is necessary to replace them.

The first step is to examine carefully the condition of the existing buildings and to undertake any urgent repairs before the underpinning work is commenced. In particular the thickness and structural condition of the walls to be underpinned should receive special consideration.

The wall to be underpinned should first be supported with flying or raking shores, which are both described later in this chapter, and holes are then excavated alongside and under the existing foundations in a suitable sequence, as illustrated in Fig. 34, whereby the sections being worked at any one time will be as far distant from one another as possible. The lengths of the excavated sections are usually 3 to 4 ft, so that the existing wall will bridge the gap satisfactorily with a minimum of support.

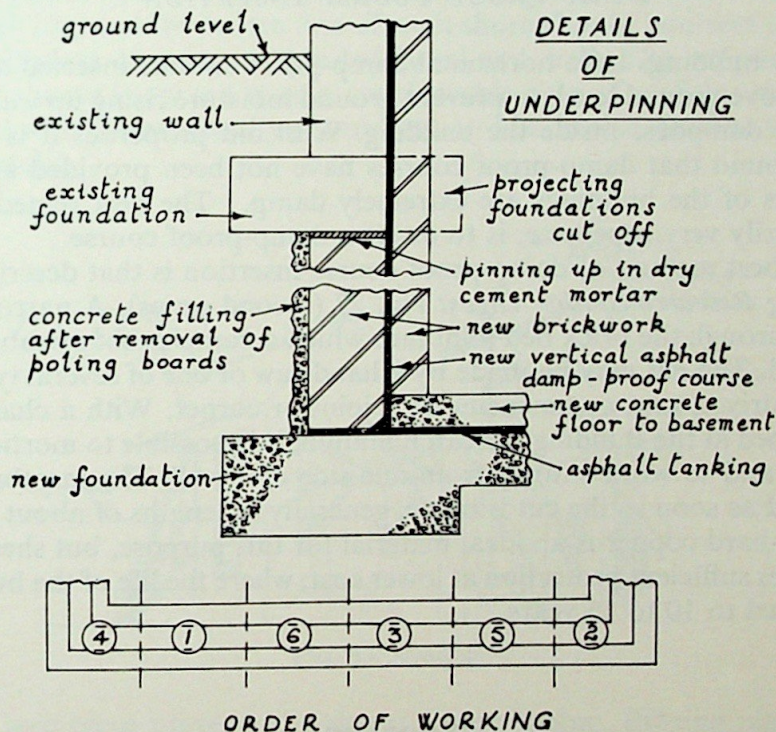


FIG. 34. Underpinning.

When excavating each hole, sufficient space is allowed in front of the wall to provide adequate working space. No earth faces must be left unsupported overnight and it is customary to limit the lengths of poling boards to 3 ft. In the case of a basement, the remaining excavation to the basement is left until the new wall and foundations are constructed.

The foundations and brickwork are constructed in each section and the back timbering removed where possible, and replaced with weak concrete. The brickwork is normally constructed in English bond and

toothings are left as the end of each section for subsequent bonding to adjacent sections.

The top of the new brickwork has to be 'pinned up' to the base of the existing wall or concrete foundation. The most usual method is to ram dry cement mortar about 1 in. thick into the gap, using a piece of board and a club hammer.

DAMP-PROOF COURSE INSERTION

All new buildings have horizontal damp-proof courses inserted at least 6 in. above ground level, to prevent ground moisture rising up walls and causing dampness inside the building. With old properties it is sometimes found that damp-proof courses have not been provided and the interiors of the buildings are extremely damp. The best remedy, but necessarily very expensive, is to insert a damp-proof course.

The best method of damp-proof course insertion is that described in *Building Research Station Digest* No. 27 (second series). A narrow slot is cut through the brick bed joint into which a damp-proof membrane is inserted. The cut may be made by a hand-saw or one of several types of power-driven saw, commencing at a joint or corner. With a chain saw developed at the Building Research Station, it is possible to mortice into a joint and so work entirely from one side of a wall. The membrane is inserted as soon as the cut is made, generally in lengths of about 2 feet.

Half-hard copper is an ideal material for this purpose, but sheet zinc provides sufficient protection at lower cost, where the life of the building is limited to 10 to 15 years.

SHORING

Shoring is introduced to provide temporary support to buildings which show signs of instability, or where alterations are being carried out. In the absence of adequate shoring the buildings might collapse, possibly causing death or injury to persons in or near the building. Municipal engineers have powers to deal with dangerous buildings and must, therefore, be familiar with the various types of shoring and when they are used.

Shoring may take a number of different forms—raking shores, flying shores, dead shores, window strutting, floor propping, etc. Fig. 35 illustrates the nature and uses of the main forms of shoring.

Shoring members are normally made of timber, often pitch pine, with all needles, cleats and wedges in hardwood. Each type of shoring will now be considered in turn:

Raking Shores

This form of shoring consists of a series of inclined timbers with their upper ends terminating with a needle and cleat against the wall to be supported and the lower ends resting on a sole plate on the ground.

The angles which the shores make with the ground should be between 45° and 70° , and the centre line of each shore should intersect those of the wall plate at eaves, suspended floors and wall. The support given by the shores is spread over a considerable area of wall by means of vertical wall pieces, usually about 9 in. $\times$ 3 in. in size, fixed to the wall with hooks.

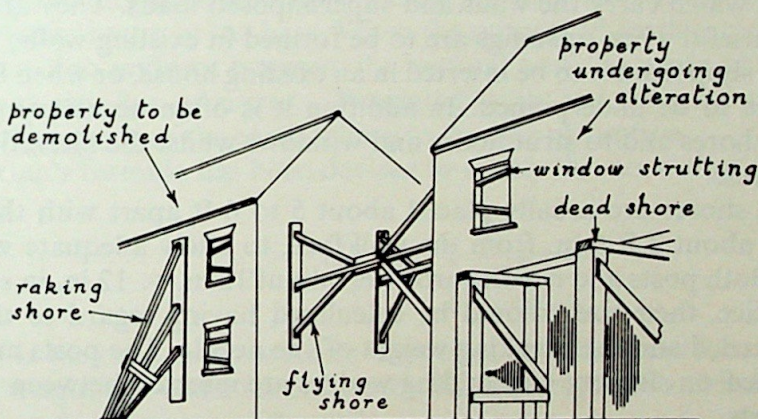


FIG. 35. Shoring.

The sole piece prevents the shores from slipping. Bracing planks or boards are nailed to the sides of the shores and wall piece to give added rigidity, and the shores are often strengthened with hoop iron binding about 2 ft above ground level.

A rough estimate of the size of shores in inches is obtained by dividing the height of the wall in feet by 5, e.g. with a 30-ft wall, the size of shores would be $\frac{30}{5} = 6$ in. $\times$ 6 in. Raking shores are normally spaced about 10 ft apart with braces running between them.

Flying Shores

These are used to provide support between buildings, where an intervening building has been demolished or across a narrow street or alley.

They are only really suitable for use of spans of 15 to 35 ft at a spacing of 10 to 15 ft. The horizontal member is called a horizontal shore and varies from about 6 in. $\times$ 4 in. to 9 in. $\times$ 6 in. according to the span. With tall buildings more than one horizontal member will be needed. These members are supported at each end by a needle and cleat fixed underneath the flying shore.

Raking struts, varying in size from 4 in. $\times$ 4 in. to 6 in. $\times$ 6 in. according to span, run from the flying shores to the floors in the two buildings. A length of straining sill, with a set of folding wedges, is nailed to each side of each flying shore, and the ends of the raking struts are fixed to them to produce a rigid framework.

Dead Shores

Dead shores consist of vertical posts supporting horizontal beams or needles, which carry the walls and superimposed loads. They are particularly useful when openings are to be formed in existing walls, such as where a shop front is to be inserted in an existing house, or when foundations are to be underpinned. In addition it is often necessary to erect raking shores and to strut floors and windows whilst the alterations are in progress.

Dead shores are usually placed about 5 to 6 ft apart with the posts located about 2 ft 6 in. from the wall face, to allow adequate working space. Both posts and needles are often about 12 in. $\times$ 12 in. in size, but in practice, their sizes should be calculated having regard to the load to be carried and the breaking weight of the needle. The posts are often supported on sleepers and folding wedges are inserted between needles and posts.

Window strutting consists of 1 in. or 1½ in. boards held in position by 2 no. 4 in. $\times$ 4 in. struts. Floor strutting usually consists of 6 in. $\times$ 6 in. vertical posts at about 4-ft centres, with 9 in. $\times$ 3 in. longitudinal plates at their top and bottom ends.

RETAINING WALLS

Retaining walls are walls built of masonry, brickwork, concrete or reinforced concrete to contain water or retain earth. The walls must be able to withstand the horizontal pressure of the water or earth, and in some cases the earth may slope above the top of the wall, when the wall is surcharged.

The pressure exerted by the earth on a retaining wall will vary with

the type of earth and is calculated in accordance with Rankine's Theory. With a water retaining wall the pressure exerted by water in pounds on one linear foot of wall, acting at right angles to the wall and at $\frac{1}{3}$ of its height above the base, is equal to

$$\frac{wH^2}{2},$$

where w is the weight of a cubic foot of water ($62\frac{1}{2}$ lb) and H is the height of wall (in feet) subjected to water pressure.

The greatest angle at which a soil will stand without slipping is known as its *angle of repose* (ϕ); typical values being 16° for wet clay and 30° for loose dry earth or gravel. Rankine's Theory indicates that the horizontal pressure exerted by the earth per square foot of wall surface is largely determined by the weight per cubic foot of soil and its angle of repose. The pressure increases uniformly with depth from zero at the top of the wall to a maximum at the base. When the support to earth is removed it slips to a line midway between the vertical and the angle of repose, known as the *line of rupture*. Retaining walls are designed with the object of preventing the earth falling to the line of rupture.

Rankine's formula has been devised to satisfy this condition and is as follows:

$$F = \frac{wH^2}{2} \times \frac{1 - \sin \phi}{1 + \sin \phi}$$

where F is the total earth pressure in pounds on one linear foot of wall, w is the weight of 1 cubic foot of earth, H is the height of wall in feet and ϕ is the angle of repose of the soil.

When designing retaining walls a number of basic rules are applied, and these are now listed:

- (1) The back face of the wall in contact with the soil is often made vertical and the outer face is battered.
- (2) With a mass concrete retaining wall the thickness at the top is often about $\frac{1}{4}$ of the height and the base thickness about $\frac{1}{3}$ of the height. In the case of a reinforced concrete retaining wall the thickness at the top of the wall will probably be about $\frac{1}{24}$ of the height of wall and the thickness at the base about $1\frac{1}{2} \times$ the top thickness.
- (3) The selected section of wall should be tested by a graphical method to ensure that the resultant of the earth pressure and the weight of the wall falls within the middle third of the base. The maximum stress at the extremity of the base and the resistance of the base to shear should also be checked.

- (4) Rankine found that where a wall is surcharged the line of thrust of the earth pressure is parallel to the slope of the ground and that its magnitude can be found from the following formula:

$$F = \frac{wH^2}{2} \cos \phi.$$

- (5) It is good policy to provide weepholes through a retaining wall at about 6-ft intervals, discharging above ground on the lower side, to drain the retained earth and so reduce its density and increase its angle of repose. The provision of a line of rubble behind the wall and adjacent to the weepholes will help in drawing subsoil water through the weepholes.

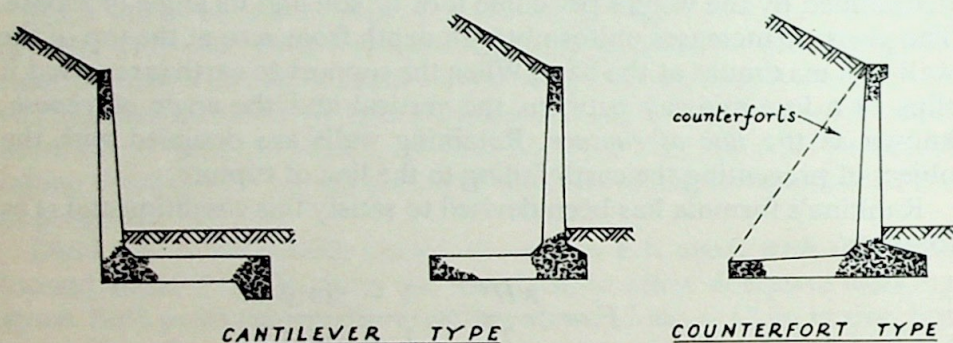


FIG. 36. Retaining walls

The main types of retaining wall are illustrated in Fig. 36. The simple cantilever type is used in the majority of cases, but the counterfort type, consisting of slab panels spanning between buttresses (counterforts), are used for walls of considerable height or those withstanding great pressures.

SEA WALLS

Municipal engineers in coastal towns are often concerned with the design, construction and maintenance of sea walls. The breaching of sea defences can cause serious damage to land and property and result in considerable loss of life, as happened in January 1951.

A popular form of sea wall in pre-war days consisted of a heavy mass concrete wall often faced with stone, surmounted by a curved coping,

and with steel sheet piling driven from the toe of the sea wall to prevent the sea undermining the wall. Timber groynes, often constructed of greenheart in the forms of piles, horizontal walings and braces, all bolted together, helped to break up the waves and to prevent the drift of littoral sand.

Since the war many varying forms of construction have been used. For instance, the East Suffolk and Norfolk River Board have constructed sea walls with a reinforced concrete parabolic section wave wall with a parapet and steel sheet piled stepped concrete apron. In addition many stretches of the sea wall are also provided with a sloping concrete revetment above the wall, to prevent loss of filling material from behind the wall.

The walls are supported by groynes, often consisting of steel tubes filled with concrete and driven through slotted steel walings laid out in herring-bone formation to hold the beach material. The East Suffolk and Norfolk River Board also takes special care to preserve the sand dune protection behind the sea wall by regular maintenance and by planting and protecting marram grass.

An unusual and ingenious form of sea wall construction was adopted at Southport in 1963 and is described and illustrated in *Municipal Engineering* (13). Briefly, the bulk of the filling to the sea wall, constructed primarily to reclaim a large area of foreshore, is of house refuse deposited in 3-ft layers and consolidated to a width of about 50 ft. A layer of hard-core was laid on top of the consolidated refuse and was later graded and surface dressed.

The seaward slope of the wall was formed with sand, covered with a 4-in. layer of sand stabilised with bituminous emulsion, supporting sett paving recovered from old highways and grouted with a mixture of sand, bituminous emulsion and 'esherlite'. The base of the wall was protected by interlocking precast concrete sheet piles, 4 ft in length, with the heads of piles stripped for connection to a concrete toe. The slopes were formed to a gradient of 1 in $2\frac{1}{2}$ and the inland slope was covered with a 4-in. layer of soil sown down with grass seed.

Yet another recent form of sea wall construction has been undertaken between the north pier of Aberdeen harbour and the mouth of the river Don. This wall incorporates a flexible facing of precast concrete blocks, vacuum cast on the Miller system, which permits de-moulding to be carried out within about four minutes; the use of steel moulds enables thousands of blocks to be cast from the same moulds. These blocks are jointed in bitumen to a slope of 1 to 2, and granite setts are cast into every third block to help in breaking high waves.

The wall is supported at its base by steel sheet piling topped with an

in situ concrete capping beam. Precast ribs, at about 30-ft centres, span between the base and the foundation to the precast coping at the top, and these give lateral stability to the blocks. The coping, which is designed to break and deflect unusually high waves, is formed of precast concrete sections prestressed together after placing. The prestressing provides a certain degree of load shedding and is also attractive in appearance. A section of this wall, under construction, is illustrated in Plate III.

The use of precast construction ensures that all components are of the highest quality with a smooth dense finish (16).

A useful article on problems of sea defence is listed in reference 17 at the end of this chapter.

BLOCKS OF FLATS

Increasing numbers of high blocks of flats are being constructed in the larger towns and cities throughout the country. The most popular type of framework would appear to be reinforced concrete, although steel frames are used on occasions, and it is interesting to note that calculated brickwork was used in a 12-storey block of flats in Birmingham (14). This latter block is constructed on a 12 ft 6 in. grid, with *in situ* reinforced concrete floors laid continuous over the internal supporting walls. The brickwork was designed in accordance with British Standard Code of Practice 111, using bricks with crushing strengths between 5,000 and 7,000 lb/in². The block is supported on a raft foundation 3 ft thick with its base 7 ft 6 in. below finished ground level.

Large panel construction is now being used to an increasing extent in flat construction. Flat panels of dense reinforced concrete can satisfy the functional requirements of structure, can provide sound insulation and fire resistance, and can be used in all the conventional plan forms including those with stairwells, corridors, balconies and scissor access, as well as tower blocks (15).

A frequently used form of construction consists of flat loadbearing panels of dense reinforced concrete using cellular, cross-wall or spine wall construction. It is essential to prevent cold bridges and resultant condensation in this form of construction. Cold bridges often occur around the edges of panels or windows, where insulation or lightweight concrete infill is displaced by dense concrete. A commonly adopted remedy is to apply internal insulating linings.

Considerable variety in texture and colour can be secured by using precast concrete panels with exposed aggregate surfaces. Timber-framed

panels are also being used to an increasing extent as façade non-load-bearing panels.

Floor construction is often formed with solid or cored slabs. Solid slabs are easier to manufacture, have greater weight and sound insulation and can act as stiff membranes in two directions. Cored slabs are easier to handle and contain useful service ducts.

CROSS-WALL CONSTRUCTION

Cross-wall construction is now being used extensively in the building of flats and houses. The cross walls are the end walls and party walls between dwellings. These walls are usually constructed of bricks, blocks or concrete, to act as fire breaks and sound barriers, as well as providing structural supports for floors and roofs, which in their turn give lateral stability to the walls.

The front and rear walls are thus relieved of any load, except their own weight, and take the form of 'curtain walls' or panel infilling between floors and roofs. They will not normally require substantial foundations.

Pitched roofs are generally designed to span from front to rear walls. The Timber Development Association has developed a series of designs for roof structures of cross-wall buildings, including stressed skin plywood panels, trussed purlins and trussed rafters, strutted purlins and common rafters, plywood girders and common rafters and plywood girders and scissors trusses. These designs suit maximum cross-wall spacings varying from 20 ft to 30 ft.

MULTI-STOREY CAR PARKS

Multi-storey car parks are now a common feature in the larger towns and cities, to cope with the ever-increasing demand for parking facilities. These structures are basically functional in design but can still be quite attractive in appearance. They generally have a fire-resistant concrete framework and can have ramped approaches or use mechanical parking devices.

The form of construction varies considerably from project to project—*in situ* concrete columns and beams supporting prestressed concrete floor units, *in situ* reinforced concrete flat slabs and mushroom columns, precast concrete H-frames supporting composite floor slabs of precast trough units with a topping of *in situ* concrete, *in situ* concrete cantilevered portal frames with precast concrete secondary beams and *in situ*

concrete ramped floor slab, and precast concrete columns with steel lifting collars threaded on and precast slabs constructed by the lift slab method, have all been used.

Similarly, a wide variety of treatments have been applied to the façades, including white concrete grillages, precast slabs surmounted by aluminium guard rails, precast concrete slabs with exposed aggregate finish sometimes edged with a light steel railing, and plastic-faced embossed aluminium sheeting.

Parking bays are normally 16 ft by 8 ft in size with circulating aisles, 20 ft to 24 ft in width. Headrooms vary from 5 ft 8 in. to 7 ft. Ramps are normally kept to gradients not exceeding 1 in 30 and a commonly accepted design floor load is 80 lb/ft².

An attractive multi-storey car park incorporating shops is illustrated in Plate IV.

RECENT BUILDING DEVELOPMENTS

The Building Research Station is continually undertaking extensive research into building and civil engineering processes, to assist in providing structures which are better fitted to their purpose and the needs of those who use them, and are as economical in construction as is practicable for their function. Much valuable information is circulated through Building Research papers and building digests, and the Station staff are always willing to give advice to municipal engineers on building problems.

Some of the more spectacular developments in building work in recent years include the mechanical handling of materials, large concrete panel construction, curtain walling, industrialised building systems, the use of prestressed concrete, new methods of thermal insulation and heating buildings, single stack plumbing and the use of plastics and many other new building materials and components.

BUILDING CONTROL

Building surveyors and building inspectors, mainly operating under municipal engineers, are responsible for ensuring that all building work is carried out to certain minimum standards of construction, as detailed in the current building regulations made under the Public Health Act, 1961. Plans of every building project have to be submitted to a local authority (county or non-county borough, urban or rural district) for

approval. After approval the contractor is required to submit notices to the local authority at various stages of construction, in order that the building inspector to the authority can inspect the work and ensure that the constructional work complies with the approved plans and the building regulations. Where contraventions occur the building inspector is empowered to take enforcement action.

The municipal engineer will often be concerned with other aspects of the proposed development, such as planning, road proposals, improvement lines, access to highways, drainage and trade waste.

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CHAPTER FIVE

Sewerage

SEWERS are pipes which convey sewage from drains, serving domestic and other properties, to sewage purification works or other points of disposal. Every local authority is required by the Public Health Act, 1936, to provide and maintain such sewers as are necessary to effectively drain their areas and to deal with their discharges. They are also required to keep sewer maps on which all public sewers are properly recorded.

Furthermore, the public have the right to discharge the contents of their drains into the appropriate public sewers, although, as explained later in this chapter, trade effluent agreements will be needed in connection with the discharge of trade wastes, which now include farm wastes by virtue of the Public Health Act, 1961.

TYPES OF SEWERAGE SYSTEM

There are three main types of sewerage system: (1) combined; (2) separate or totally separate and (3) partially separate. Each system is now considered.

Combined System

In a combined sewerage system, there is one sewer pipe which receives all types of drainage (foul and surface water). This method is often used in coastal towns where no treatment of the sewage takes place and is sometimes used in village schemes where the maximum flow is rather limited.

The adoption of this type of sewerage system simplifies and cheapens the house drainage system, as a single drain takes the discharges from foul appliances, wastes and rainwater pipes. This ensures that the house

drains will be well flushed during times of storm and eliminates the possibility of connecting a house drain to the wrong sewer.

With regard to the sewerage system itself, there is a possibility of silting in a larger pipe unless self-cleansing velocities are obtained with peak foul flows. Storm overflows are often needed and these sometimes cause pollution of watercourses, and it can prove costly when vast quantities of surface water have to be pumped. Furthermore, the influx of large quantities of surface water can make for difficulties at the sewage disposal works.

Separate System

In a separate sewerage system there are two pipes, one to receive foul drainage and the other to take surface water. The domestic sewage and trade effluents are treated at a sewage disposal works, whereas the surface water is usually discharged into watercourses. This system involves two separate runs of drains to properties and results in additional expense in both provision and maintenance. There is a risk of a drain being connected to the wrong sewer and there is no flushing of foul drains with surface water.

No storm overflows are required on sewers laid to this system, but foul sewers may need periodic flushing where flows are small or the pipes laid to flat gradients. Pumping costs are, however, reduced to a minimum and it facilitates the operation of the sewage disposal works.

Partially Separate System

This is a compromise between the first two methods whereby there are two sewers, one taking foul drainage together with some surface water often from back yards and rear roof slopes, while the other sewer usually takes the surface water from highways and front roof slopes.

This system simplifies and cheapens the house drainage arrangements and enables the foul drain to be flushed in times of storm. The sewerage system has most of the advantages and disadvantages of the combined system but to a lesser extent.

When selecting the type of sewerage system to be adopted for an area, all the circumstances must be considered including the economics of each method.

SOIL SEWERAGE

Soil or foul sewerage is concerned with the conveyance of foul drainage from properties, i.e. the discharges from water closets, urinals,

baths, lavatory basins, sinks, trade process equipment and farm buildings.

In order to design foul sewers it is necessary to know the population to be served and to decide on a discharge figure per head of population. When determining the population figure it is often necessary to allow for probable increases in population in the area over a certain period, such as 20 years. Consultation with the staff of the local planning authority will be of great value in this respect. Existing population figures may be obtained from a number of sources, such as statistics prepared by the Medical Officer of Health or collected by the local planning authority, or the census published by the Registrar General; but more often they are obtained by a survey of properties on the ground, checked against Ordnance survey sheets.

When working from the number of dwellings it is necessary to decide upon an occupancy rate, and this may well vary from district to district depending on the type and class of property. The Code of Practice (see reference 1 at the end of this chapter) suggests 3.5 persons per dwelling and this is a satisfactory average figure.

The volume of foul drainage is closely related to the water consumption in the area. The water authority can supply details of water consumption per person per day for domestic use and also the figure for industrial use, which is separately metered. In addition it is sometimes necessary to pick up industrial premises which have their own private means of supply from artesian wells, boreholes, etc. Furthermore, it would be prudent to allow for possible future changes in water consumption arising from an increased provision and use of sanitary appliances and hot water supply systems, the changing character and residential densities of districts due to redevelopment and the extension of industrial development.

The Code of Practice (1) suggests a discharge of 50 ghd (gal per head per day), from residential areas, whilst a figure of 40 gal was used in the design of a new main sewer at Chelmsford (2). This latter figure was based upon the actual domestic water consumption and included an allowance of 5 gal for future increases. On investigation the author found that there were considerable variations, but generally adopted design figures for domestic drainage were 40 ghd in urban areas and 30 ghd in rural areas. The latter figure may not, however, be adequate to meet future needs.

The flow from industrial premises varies considerably and in a selected list of small industrialised country towns, ranged from 7 to 15 ghd. With existing sewerage systems allowance has also to be made for infiltration of ground water into the sewers, and this can, on occasions, reach quite alarming proportions.

It can also generally be assumed that half the total domestic flow will be discharged over a period of 6 hours. Taking a design basis of 3.5 persons per dwelling and 40 gal per head per day, all discharging in 12 hr, a flow of 140 gal per dwelling per day of 12 hr is obtained.

Discharges per acre for varying house densities would then be

8 houses per acre	0.25 ft ³ per min per acre
12 " "	0.37 " "
16 " "	0.50 " "

The Code of Practice (1) suggests that pipes should be capable of carrying a minimum of 4 times the average flow.

These figures indicate the relatively small flows of domestic sewage, in the absence of any surface water, and the limited sewer capacity needed to cope with them (for instance a 6-in. pipe sewer at a gradient of 1 in 80 will take approximately 40 cumins or ft³ per min).

Trade Wastes

Trade wastes or effluents are the liquid discharges from industrial premises and they vary tremendously in amount, character and chemical content. In the absence of pre-treatment, some trade effluents can cause deterioration of sewers, manholes and pumping machinery. The worst effluents in this respect are acidic wastes, liquids at high temperatures and effluents containing certain inorganic sulphates or sulphides, or ammonium or metallic salts. In some cases suspended matter in trade effluents can cause blockage of sewers, and in other cases may give rise to dangerous conditions for workmen in sewers or adversely affect the operation of sewage purification plant.

For these reasons it is essential that strict control is exercised over the discharge of trade effluents into public sewers by means of trade effluent agreements, and that suitable pre-treatment should be carried out by the industrialist where necessary.

In all cases the first essential is for the municipal engineer to determine the temperature, chemical contents, probable maximum discharge of the proposed effluent per day and the highest rate at which it is proposed to be discharged. Where there is any doubt it is advisable to secure the services of an analytical chemist to determine the probable effect on the operation of sewers and sewage disposal works and the nature and extent of pre-treatment that is desirable.

Prior to the discharge of any trade effluent into a public sewer, a trade effluent agreement should be drawn up with the industrialist covering all or any of the following matters:

- (1) The installation of plant at the factory to partially purify, to remove harmful contents or cool hot effluents to a prescribed temperature. All of this work is to be carried out at the industrialist's expense. A limit is often placed on the pH value of the effluent and its suspended solids content and oxygen absorption capacity.
- (2) Payments to be made to the local authority to cover the additional cost of treatment of the trade effluent, which is usually metered and a charge made for the treatment per thousand gallons. (The charge is often assessed on the pollution load, based on the volume and strength of effluent.)
- (3) Provision for members of the municipal engineer's staff to make periodic inspections of the industrialist's plant, to ensure that the effluent is receiving proper treatment.
- (4) The local authority is permitted to take an agreed number of samples per year (often four) for independent analysis, and the cost of the analysis is often paid direct by the industrialist.
- (5) On signing the agreement, the local authority normally receives a payment to cover the cost of the fees of consultants and/or analytical chemists and any other preliminary expenditure.

Some of the worst types of trade effluents are those discharged from tanneries, gasworks, dairies, sugar factories and chemical works. It is sometimes found that the industrialist has not sufficient spare land available for treatment of trade effluent, and it may be necessary to dilute the effluent to a specified ratio and for the local authority to carry out the whole of the treatment. Consideration must also be given to the ratio of trade effluent to domestic sewage—a large tannery in a small country town can create serious problems.

Farm Wastes

In rural areas the discharge of farm wastes can cause local authorities much concern when, for example, the drainage from extensive cowsheds enters the sewerage system serving a small village. Under the Public Health Act, 1961, these discharges are now regarded as trade effluents and the local authority can make charges for new discharges of farm waste.

It is often possible for a farmer to install his own purification plant and, in any event, he should be required to install some pre-treatment plant. The farm wastes, by virtue of their amount and content, can create serious problems and much expense in the construction and operation of the local authority's sewage purification plant. A case was described in *The Rural Surveyor* where the cost of the sewage disposal works serving

a village with a population of about 140 was doubled in order to cope with the discharge from 50 cows.

SURFACE WATER SEWERAGE

Preliminary investigations, prior to the design of a surface water sewerage system, are outlined in the Code of Practice (1) and include the location of all watercourses with gaugings or estimated flows. Consideration will now be given to methods of design used for surface water sewerage schemes.

Rainfall Intensity

The duration and intensity of heavy rainfall in the area has an important bearing on the design of the surface water sewers, which will have to cope with these conditions. Where sufficient information on past storms is available the information should be plotted on an intensity-duration chart, together with the Ministry of Health curve. Recordings above the latter curve indicate exceptional conditions. Where these conditions only operate very infrequently in a relatively flat area of open development they can probably be safely discounted, but if they operate in a steep-sided valley or a closely built-up area, then storms as infrequent as once in ten years may deserve consideration. The Code of Practice (1) recommends drainage authorities to set up automatic recording rainfall gauges. Information on rainfall can be obtained from the British Rainfall Organisation, Meteorological Office. A heavy snow-fall followed by a rapid thaw can produce a run-off equivalent to that of a heavy rainstorm.

The Ministry of Health formula, which follows, has been widely used to determine rainfall intensity:

$$R = \frac{30}{T + 10}, \text{ where } T \text{ is between 5 and 20 minutes}$$

or

$$R = \frac{40}{T + 20}, \text{ where } T \text{ is between 20 and 100 minutes}$$

where R = rainfall intensity in inches per hour and T = time of duration of storm in minutes or time of concentration (time of flow in longest sewer to point under consideration, calculated from full-bore velocities, plus an allowance for time of entry).

Surface Water Run-off

There are two main problems in determining surface water run-off

- (1) To decide the proportion of rainfall that has to be considered in the design calculations.
- (2) To determine the rates of flow in the various parts of the sewerage system.

The type of rainfall which normally taxes the sewerage system to the greatest extent is the storm of moderate intensity and long duration. Not all the rain falling in a catchment area reaches the sewers. Some passes through the surfaces making up the catchment area, some is retained on these surfaces and some evaporates. The amount of these losses and the rates at which they will occur depend upon a number of factors, including the nature of the surfaces, the type of storm and even the nature of the preceding weather. The proportion of the rainfall that enters a sewer is known as the 'impermeability factor', whilst the difference between the total rainfall and the total run-off during a storm has been referred to as the 'rainfall loss' (3).

A widely used set of impermeability factors is that devised by Kuichling in 1909, and this is now listed.

TABLE 6

<i>Type of surface</i>	<i>Impermeability factor (%)</i>
Watertight roof surfaces	70—95
Asphalt pavings in good order	85—90
Stone, brick and block pavements with tightly cemented joints	75—85
Stone, brick and block pavements with open or uncertain joints	50—70
Inferior block pavements with open joints	40—50
Macadam roads and paths	25—60
Gravel roads and paths	15—30
Unpaved surfaces, railway yards and vacant plots	10—30
Parks, gardens, lawns and meadows, depending on surface slope and character of subsoil	5—25

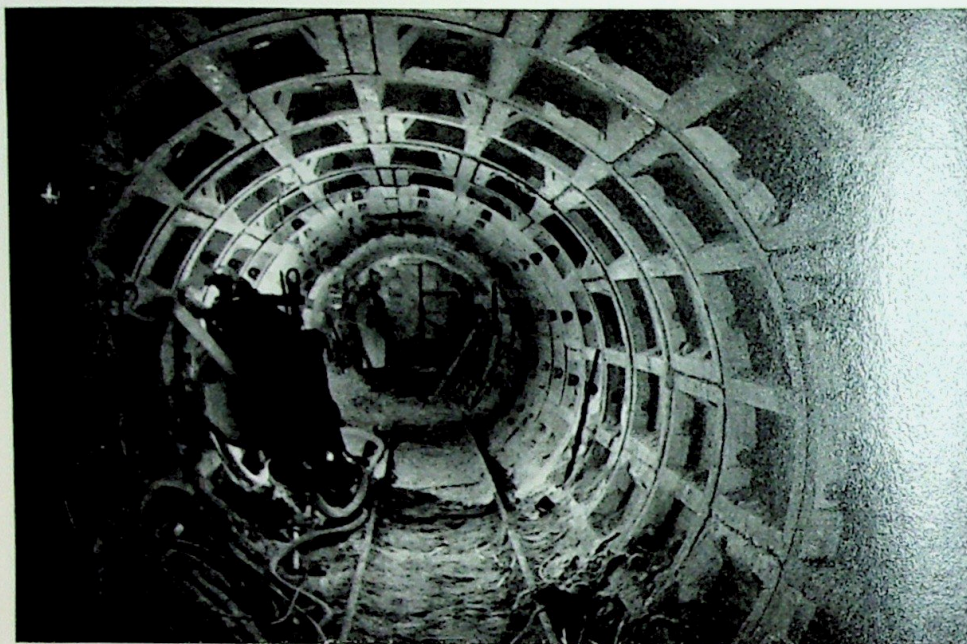
For housing estates the impermeability factor is often calculated on the following basis:

$$\text{Percentage impermeability} = 10 \sqrt{N}$$

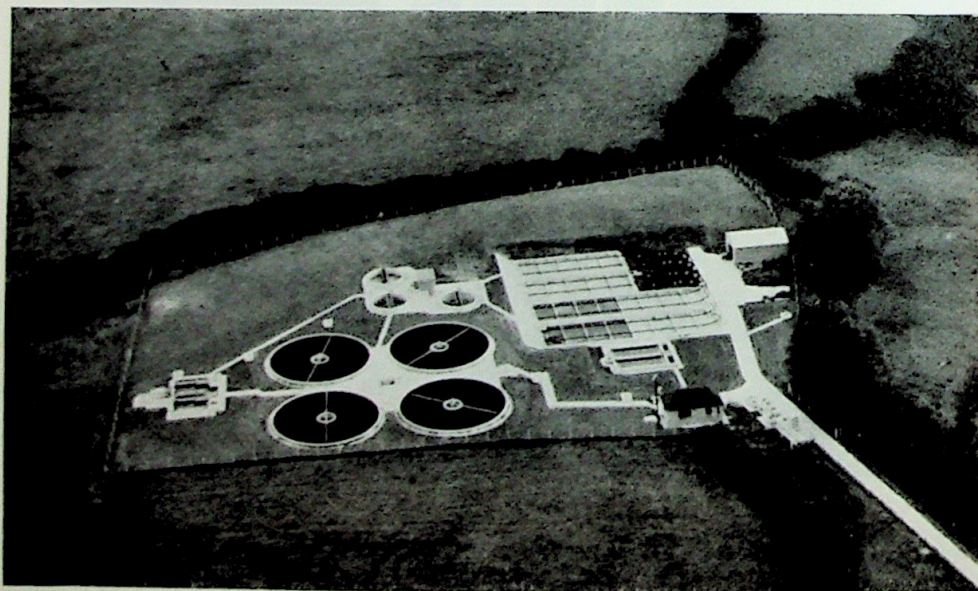
where N = number of houses per acre.



IV Multi-storey Car Park, Bedford



V Precast Concrete Tunnel Lining to Trunk Sewer, Great Yarmouth



VI Small Sewage Disposal Works, Sussex

Taking a density of 16 houses per acre, the impermeability factor would be $10\sqrt{16} = 10 \times 4 = 40$ per cent.

High run-offs can be obtained from open land under certain conditions. For instance, after a spell of dry weather when the surface has hardened appreciably or following a prolonged period of rain when the ground has become saturated. This latter condition arose at Haverhill, Suffolk, in June 1958 when the Stour Brook, with a limited catchment area, overflowed its banks and flooded the centre of the town during moderate rainfall, following a fortnight when there were long periods of light rain.

In designing a surface water sewerage system it is necessary to allow a 'time of entry'. This is the average time which rain falling in the area will take to reach the sewers. This will be affected by the nature and slopes of surfaces and the location of inlets to the sewerage system. A commonly adopted allowance in urban areas is 3 to 5 minutes.

The total run-off is generally calculated using the Lloyd-Davies or rational formula:

$$Q = 60.5 ApR$$

where Q = run-off in cumins, Ap = impermeable area in acres, R = rainfall in inches.

As an example, consider the small layout plan of a sewer included in Fig 37, which drains area I , scheduled for private residential development at a density of 10 houses to the acre.

$$\begin{aligned}\text{The impermeable area} &= 5.29 \times 10 \sqrt{10} \\ &= 5.29 \times 31.6 = 1.67 \text{ acres.}\end{aligned}$$

To determine the run-off at $M.H.4$ it is necessary to calculate the time taken for the storm water to reach this point (time of concentration). Assuming a 9 in. diameter pipe at a gradient of 1 in 100, the velocity of flow is 230 ft per min and the time taken to pass from $M.H.1$ to $M.H.4$ is 3.45 min (793/230).

$$\begin{aligned}\text{The time of concentration is } &3.45 + 3.00 \text{ (time of entry)} \\ &= 6.45 \text{ min.}\end{aligned}$$

$$R = \frac{30}{T + 10} = \frac{30}{16.45} = 1.82 \text{ in. per hr}$$

$$Q = 60.5 \times 1.67 \times 1.82 = 184 \text{ cumins (ft}^3 \text{ per min)}$$

A suitable pipe size would probably be 12 in., as a 12 in. pipe at a gradient of 1 in 150 has a capacity of 190 cumins (determined by hydraulic slide rule or from design charts).

Time-Area Diagrams

The majority of surface water sewerage systems have been designed on the basis of time-area diagrams, now described by the Road Research Laboratory as area/time diagrams (3).

A time-area diagram is illustrated in Fig. 37, where each acreage of impervious area is plotted vertically on a horizontal base of time, commencing at the point of entry and indicating by a diagonal line the time of concentration (including time of entry). A summation curve indicates the total areas draining into the system at any given point. By extracting the area and time of concentration, the amount of rainfall and total run-off can be calculated using the formulae given earlier in the chapter.

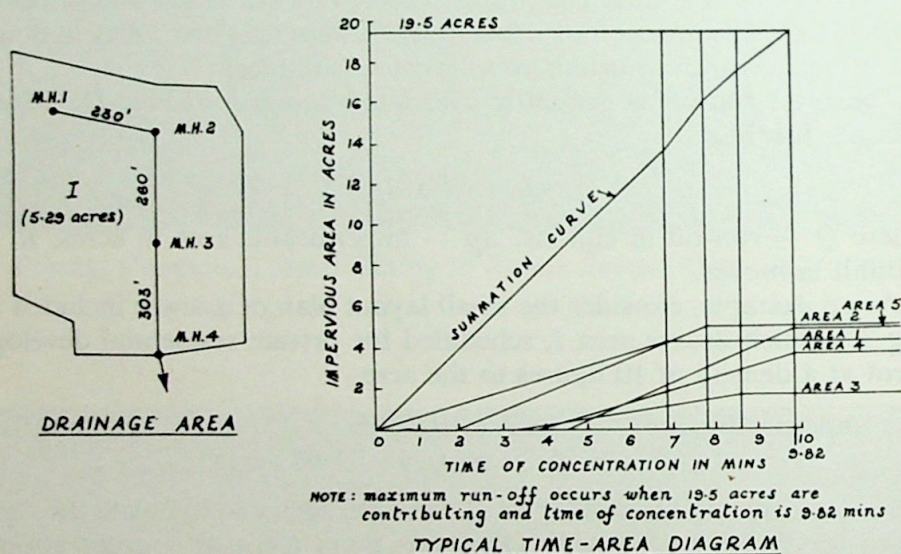


FIG. 37. Time-area diagram and drainage area.

Road Research Laboratory Hydrograph Method

The Road Research Laboratory has carried out extensive investigations into the design of urban sewerage systems, with particular reference to the relation between the rate of rainfall and the rate of flow in sewers (3). As a result of these investigations, the Laboratory has come to the conclusion that the rational (Lloyd-Davies) formula is a satisfactory design method for sewers for relatively small areas, such as small housing estates and villages, in which there are no sewers larger than about 24 inches in diameter. The Laboratory method is, however, considered to be an accurate and reliable means of calculating run-off

hydrographs for all urban areas, as the result of an analysis of specific examples in various parts of the country. The Laboratory used rainfall recorders which recorded total rainfall and rate of rainfall, and standing-wave flume or V-notch flow recorders at the lower ends of the sewerage systems.

Each drainage area was split into sub-areas and time-area diagrams were prepared. The rate of rainfall/time curve was then calculated for each recorded storm, in the form of a step diagram using the same unit-times as those into which the time-area diagrams had been divided. Finally, the hydrograph was calculated, assuming that at the end of the first unit-time the rate of run-off was the product of the first rate of rainfall and the first increment of area (from time-area diagram); at the end of the second unit-time the first rate of rainfall would be running off from the second increment of area, together with the second rate of rainfall from the first increment of area.

The Laboratory expressed the build-up of the hydrograph in the following way.

$$\begin{aligned}q_1 &= (i_1 \times A_1) \\q_2 &= (i_1 \times A_2) + (i_2 \times A_1) \\q_3 &= (i_1 \times A_3) + (i_2 \times A_2) + (i_3 \times A_1)\end{aligned}$$

where q = run-off, i = rainfall and A = area.

Modifications were needed to allow for 'loss of rainfall' and for temporary retention in the pipe, and these are well explained and illustrated in the Road Research Technical Paper (3). The volume held in retention, for any depth of flow at the outfall, is the total volume of the system multiplied by the area of flow at the outfall expressed as a proportion of the total cross-sectional area of the outfall pipe. In this way the retention curve can be built up, either by calculating the area of flow and the discharge at various depths, or by using tables of proportional values for velocities and discharges in circular sewers and pipes running partly full.

SEWER DESIGN

Sewers should be laid at gradients which will give self-cleansing velocities under reasonable conditions of flow. Recommended velocities are 2.5 to 3 ft per sec for pipes up to 9 in. diameter and 2.5 ft per sec for larger pipes: 6 ft per sec is often regarded as a desirable maximum velocity, with 10 ft per sec as an absolute maximum, particularly if there is grit present in the pipes.

The velocity of flow in a pipe can be found from the Chezy formula:

$$V = c\sqrt{mi}$$

where V = velocity in ft per sec

c = a constant, often taken as 100 but varying with the size, condition and material of the pipes—e.g. older, rougher pipes would have a value less than 100

m = hydraulic mean depth $\frac{(\text{cross sectional area of flow in ft}^2)}{(\text{length of wetted perimeter in ft})}$
when pipe is flowing full bore or half the depth, m is 0.25

i = gradient $\frac{(\text{fall in ft})}{(\text{length in ft})}$

The velocity of flow in sewers is often calculated from the formula devised by Crimp and Bruges:

$$v = 124 \sqrt[3]{m^2 \sqrt{i}}$$

where v = velocity in ft per sec

m = hydraulic mean depth

i = gradient

Having found the velocity the capacity of a pipe can readily be calculated from the formula:

$$Q = Av$$

where Q = capacity in ft³ per sec or min

A = cross sectional of flow in ft²

v = velocity in ft per sec or min

The most commonly used formula is probably that devised by Crimp and Bruges:

$$Q = 3.072D \sqrt[3]{i}$$

where D = diameter of pipe in ft.

Crimp and Bruges formula is used extensively in practice as comprehensive sets of tables and graphs are available, based on this formula, giving capacities and velocities for a wide range of pipe sizes laid to every conceivable gradient. Birmingham city engineer's department produced an excellent hydraulic slide rule, before the last war, by which the calculation of pipe sizes and velocities for circular and egg-shaped sewers, using Crimps and Bruges or Kutters formulae, became a very speedy operation.

Minimum gradients of sewers to give self-cleansing velocities under conditions of reasonable flow would be 1 in 150 for 6-in. pipes and 1 in 250 for 9-in. pipes.

When designing a sewerage system it is important to adopt a logical sequence of operations. Many years ago the author was privileged to serve under John Dossor, Consulting Engineer of York, in whose office the following procedure was adopted for the design of rural sewerage schemes.

- (1) Determine discharge factors, persons per acre, impermeability factors, etc.
- (2) Prepare a 1/2500 plan showing previously taken ground levels and invert levels of existing sewers. Lay down possible lines for proposed sewers and plot sections with existing sewers shown (scales—1/2500 horizontal and 20 ft to 1 in. vertical). Manhole positions provisionally fixed and indicated on plan and section. (Manholes are generally required at humps and hollows, changes of direction or grade and at intervals not exceeding 300 ft. It is advisable to avoid positions in roads near channels and in fields away from hedge lines.)
- (3) Prepare a drainage area plan showing the area to be drained with surface utilisation indicated on it where relevant. The drainage area is then subdivided having regard to the way in which the run-off will reach the sewers. A division will normally cross the sewer at each manhole; the exceptions being at the heads of sewers where the first area extends to the second manhole. Each area is assumed to drain to the upper manhole as pipe sizes cannot be varied between manholes. Where a branch sewer has to be partially outside the original drainage area, the area is best extended to include the additional area that can conveniently be drained into the branch. Consideration should also be given to the deletion of areas which can only be drained at excessively high cost.
- (4) On the sections show at least once on each sewer run between manholes, the minimum depth at which connections can reach the sewer. To arrive at this depth, allow 2 ft 9 in. below the level of the furthest house and a gradient of 1 in 50 from the house to the sewer. Allow for passing under existing sewers or services (gas and water)—the latter may usually be taken as about 3 ft deep. Any significant levels which control sewer depths should be shown on the sections.

Approximate invert lines are now drawn at the minimum depths, keeping the crowns of the pipes level at manholes and connections. Finalise the positions of manholes on plan and sections. The

manholes at the heads of sewers normally have a depth of about 3 ft 6 in.

The sewers are then designed in detail, preferably using a sewer design schedule of the type illustrated in Fig. 38, taking the branch sewers first and ensuring self-cleansing velocities throughout.

SEWER CONSTRUCTION

Sewers are constructed in a variety of materials depending on the size of the sewer, soil conditions, whether constructed in tunnel or open cut, etc. The principal forms of construction will now be briefly considered.

Sewer Materials

Glazed Vitrified Clay or Salt-glazed Ware Pipes to B.S. 65 usually of British Standard quality are used extensively for smaller diameter sewers. They are, however, seldom used for diameters in excess of 18 inches. These pipes are mainly supplied in 3-ft lengths and are usually laid with rigid joints of cement mortar (1:2) and tarred gaskin. Various types of flexible joint are available, the latest incorporating a band of polyester on spigots and sockets of pipes with a rubber gasket ring sandwiched between them. This gives a superior self-aligning but more expensive joint.

Concrete Pipes to B.S. 556 are made in diameters ranging from 6 in. to 42 in. and in lengths of 3, 4, 5 and 8 ft. They may be constructed with rapid hardening, high alumina or sulphate-resisting cement and may be unreinforced or reinforced in one of four classes, withstanding test pressures ranging from 20 to 100 lb/in². They can be laid with rigid joints—ordinary spigot and socket, self-centring spigot and socket, rebated or ogee—the latter two joints being used mainly for surface water sewers. The main form of flexible joint incorporates a rubber ring which is quickly made by unskilled labour, can be used in waterlogged trenches and will successfully withstand a certain amount of deflection.

Cast Iron (Centrifugally Spun) Pipes to B.S. 1211 are made in 4 classes of which class B is the best suited for sewerage work. These pipes are made in a wide range of diameters from 3 in. upwards and in lengths of 12 ft, 13 ft 1½ in. (4 metres), 16 ft and 18 ft. These pipes are generally jointed with rigid joints of caulked lead but many types of flexible joint are available. Cast iron pipes are particularly suitable for use in river crossings,

SEWER DESIGN SCHEDULE

AREA SCHEDULE				REMARKS	INFLUX			LOAD						SEWER												
AREA Nº	TOTAL AREA	IMP. AREA	DW.F. cfm		AREA Nº	IMPAREA acres	DW.F. cfm	M.H. Nº	INDEX LETTER	DIS. AREA IMPERV acres	DW.F. cfm	RUN-OFF /acre cfm	MAX. DIS. cfm	CAP. FULL cfm	SIZE in. dia.	GRADE 1 IN	FALL ft.	DIST. ft.	VELOCITY feet per min.				T mins.	SOFF.	INVT.	G.L.
																				FULL	MAX	DIS	DW.F			
1	2.52	.015	.34					1		.015	.34	128	2.26	40	6	80	3.10	250	205	143	62	4.2	47.75	47.25	54.4	
2	2.16	.013	.28		1	.015	.34	2		.028	.62	117	3.99	100	9	110	2.78	305	230	92	58	5.5	44.65	44.15	50.3	
3	1.76	.010	.23		2	.013	.28	3		.066	1.13	113	8.64	100	9	110	1.00	110	230	120	76	6.0	41.87	41.12	48.7	
4	4.73	.028	.62		3 & 4	.038	.85	5		.082	1.47	110	10.47	86	9	150	0.57	85	195	116	80	6.5	40.87	40.12	49.0	
5	0.33	.002	.04		5, 6 & 7	.016	.34	8														7.0	40.30	39.55	49.5	
6	2.13	.013	.28																							
7	0.14	.001	.02																							
								4		.028	.62	130	4.26	42	6	71.5	2.66	190	217	130	74	4.0	44.53	44.03	48.1	
					4	.028	.62	3														4.8	41.87	41.37	49.5	
								7		.013	.28	132	2.00	50	6	51	4.90	250	257	120	65	3.7	49.10	48.60	55.9	
					6	.013	.28	6		.015	.32	123	2.21	50	6	51	3.33	170	257	130	70	4.7	44.20	43.70	52.6	
					5	.002	.04	5														5.4	40.87	40.37	49.0	

FIG. 38. Sewer design schedule.

fixing to piers above low-lying land and in sea outfalls and pumping mains.

Asbestos Cement Pipes are made from asbestos fibres, Portland cement and fillers, in 4 metre lengths and in diameters ranging from 4 in. to 21 in., with semi-rigid joints of asbestos cement sleeves and rubber rings. They are suitable for domestic sewage and most trade effluents and will successfully withstand aggressive soils. They are light, strong and easy to lay and pressure pipes are available for use in pumping mains.

Pitch Fibre Pipes are made in diameters up to 8 in. and in lengths of 8 ft. The joints consist of pitch fibre couplings fitted over the tapered ends to the pipes. They are strong, durable and will stand deflection and have been employed on rural sewerage schemes.

Brick Sewers are occasionally used particularly where egg-shaped sewers are required, for flat gradients or where a tremendous range of flow is involved, to give greater depths at lower rates of flow. It is advisable to use engineering bricks complying with B.S. 3921.

Precast Concrete Segments are often used for the construction of large sewers in tunnel. The segments are 2 ft in length and are bolted together with a layer of bituminous packing between the sections to form a complete ring. The segments are usually about 2 in. thick, heavily reinforced, and with 3 in. deep ribs. The internal recesses are filled with concrete and a concrete lining then applied to give a smooth homogeneous inner surface. A 1½ in. diameter grout hole is normally provided in each section for filling any voids outside the segments with cement grout, after which the holes are plugged.

A useful article on the construction of sewers in tunnel is listed in reference 8 at the end of this chapter.

Plate V shows concrete segments laid on a trunk sewer contract at Great Yarmouth. The hand excavated tunnel face is shown boxed up for a long weekend and in the foreground is a grout pan with compressed air and water supply.

Cast Iron Segments are still used on occasions for tunnel linings but have been largely superseded by precast concrete segments.

In situ Concrete, mass or reinforced, is used extensively for culvert construction, primarily for the carriage of surface water. Such culverts

are made to a variety of shapes and sizes according to circumstances. Concrete is sometimes used to strengthen the underside of defective brick arches to old brick culverts.

A typical reinforced concrete culvert is illustrated in Fig. 39.

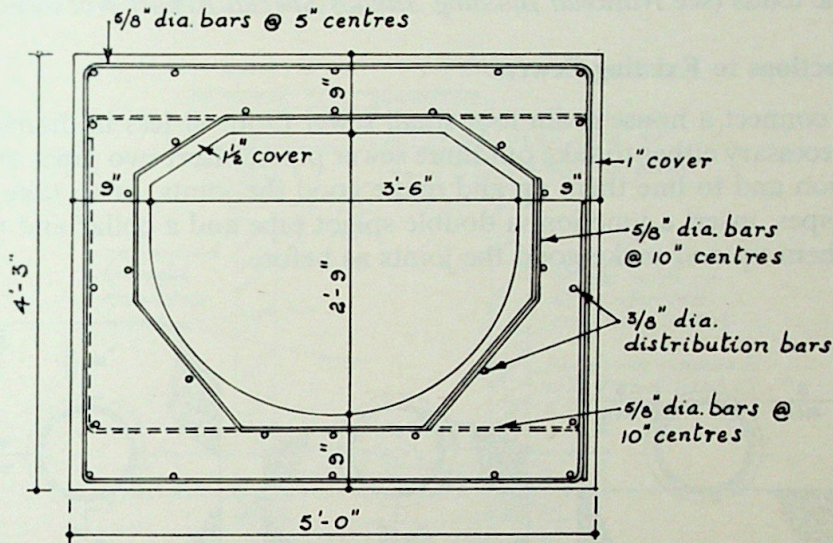


FIG. 39. Reinforced concrete culvert

Concrete Support and Protection to Pipe Sewers

Concrete protection to sewer pipes is needed in certain situations and can take one of three forms.

- (1) Bed, 6 in. deep, on poor trench bottom, although the Code of Practice (1) recommends compacted gravel or piles in exceptional cases.
- (2) Haunching and bed, when pipes are laid under roads at depths of 4 to 20 ft or between 14 and 20 ft in other situations.
- (3) Surround to pipes laid in heading or tunnel, under buildings, or when less than 4 ft or over 20 ft deep.

The various forms of concrete protection are illustrated in Fig. 40.

Considerable research has been undertaken by a Ministry of Housing and Local Government working party and the Road Research Laboratory in recent years to determine the loads causing failure of sewer pipes under roads (see references 9 and 10). It is now considered that sewers under roads should be designed to withstand 36 units of HB loading as

described in B.S. 153 (36 ton per axle), with an impact factor of 1.3 to allow for the additional load generated by the passage of the vehicle over road surface irregularities, and that a factor of safety of $1\frac{1}{4}$ should be applied. It is becoming quite common practice to use sewer pipes with flexible joints which, together with their bedding, are designed to carry specific loads (see *National Building Studies Special Report No. 32*) (14).

Connections to Existing Sewers

To connect a house drain to a small sewer (9 in. or less in diameter) it is necessary either to take out three sewer pipes, insert two pipes and a junction and to line them up and make good the joints, or to take out two pipes, insert a junction, a double spigot pipe and a collar and then line them up and make good the joints as before.

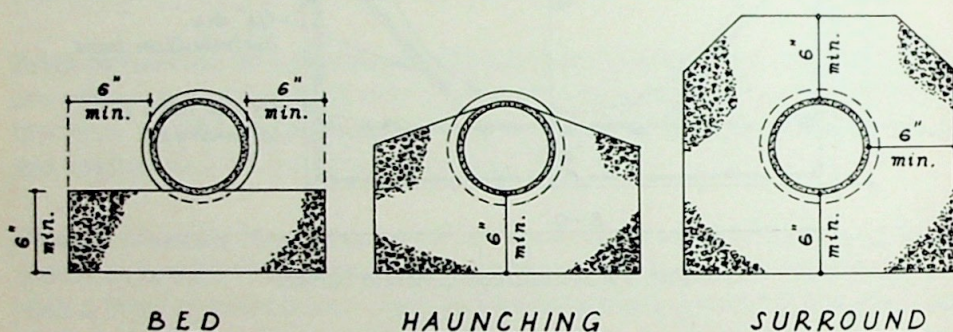


FIG. 40. Concrete protection to pipes.

With connections to larger sewers it is customary to use a saddle, which consists of a socket attached to a shoulder which fits over the curved surface of the sewer. A hole is broken in the top half of the sewer, which is then carefully trimmed to fit the aperture in the saddle, and finally the saddle is jointed to the sewer with cement mortar and the connection surrounded with concrete.

MANHOLE CONSTRUCTION

Spacing of Manholes

Manholes constructed on sewers less than 3 ft in diameter should be provided at changes of size, direction or gradient of sewers, heads of sewers or branches, junctions of two or more sewers and at intervals not exceeding 300 ft to permit satisfactory rodding.

On larger sewers the spacing is governed by the need for removal of silt or other obstructions, conveyance of materials for repair work and ventilation for men working in the sewer. Distances of 600 to 800 ft are mentioned in the Code of Practice (1) and where a sewer exceeds 6 ft in diameter, a spacing allowance to 100 ft per ft of diameter of sewer, up to a maximum of 1,200 ft is given.

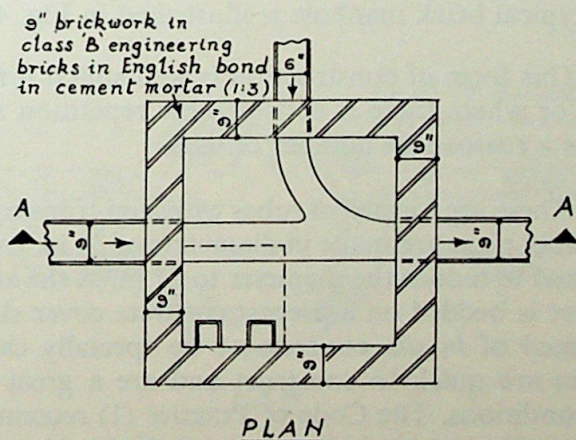
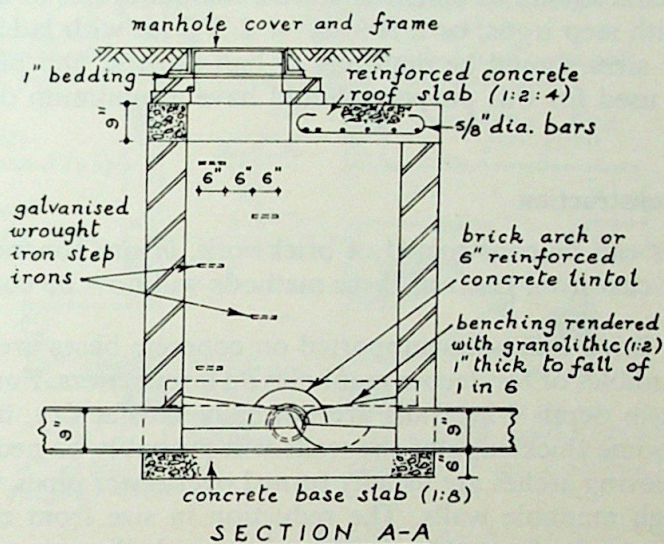


FIG. 41. Brick manhole.

Manhole Sizes

For shallow manholes a minimum chamber size of 4ft by 2 ft 6 in. (4 ft 1½ in. × 2 ft 7½ in. for brick chambers) is recommended. There

should be a minimum of 6 in. width of benching on each side of the main channel and with sewers 15 in. or more in diameter, one benching should be at least 1 ft 2 in. wide so that a man can stand on it.

For deep manholes on small sewers and manholes on large sewers, a benching or landing should be provided of sufficient size to enable two men to stand on it.

Access shafts should be constructed to a minimum size of 2 ft 6 in. $\times$ 2 ft 3 in. with step irons, or 2 ft 9 in. $\times$ 2 ft 3 in. with ladders. Brick access shaft sizes should be multiples of half-a-brick, and precast concrete tubes used for this purpose should have a minimum diameter of 2 ft 3 in.

Forms of Construction

Manholes can be constructed of brickwork, *in situ* concrete, precast concrete or cast iron. Each of these methods will now be considered.

Brickwork. Brick manholes supported on concrete bases are useful for shallow manholes or for deeper manholes on large sewers. For manholes up to 10 ft in depth 9-in. walls are normally satisfactory, but beyond this depth some thickening of the walls will probably be necessary.

Brick relieving arches are usually turned over sewer pipes where they pass through manhole walls. The reduction in size from chamber to access shaft can be formed by brick arches, corbelling or a reinforced concrete slab. A typical brick manhole is illustrated in Fig. 41.

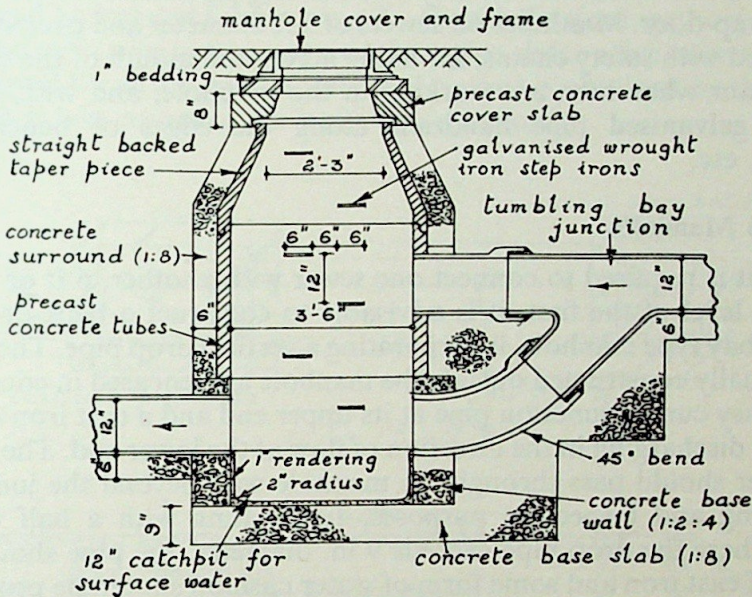
In situ Concrete. This form of construction is well suited for irregular-shaped manholes or where there is considerable repetition so that the shuttering receives a reasonable number of uses.

Precast Concrete. These are formed of tubes with step-irons cast in at the factory. The chamber rings are made in diameters of 36 in. to 72 in. and taper pieces are used to reduce the diameter to 27 in. at the access shaft. The manhole cover is bedded on a precast concrete cover slab and the base may be formed of *in situ* concrete or be specially cast. Precast concrete manholes are quick to construct and are a great asset with difficult ground conditions. The Code of Practice (1) recommends that the chamber rings and taper should be surrounded with 6 in. of concrete. A typical concrete manhole is illustrated in Fig. 42.

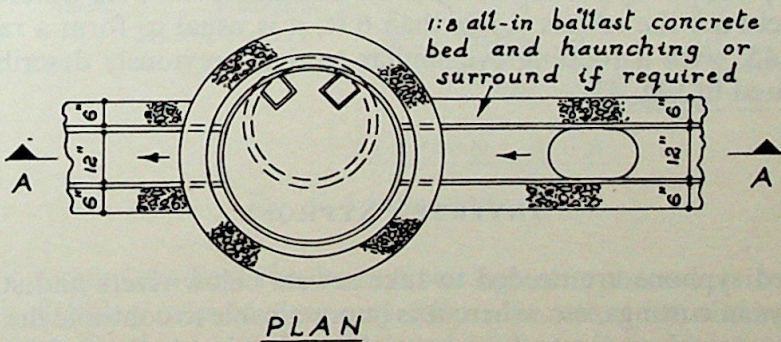
Cast Iron. Manholes can be constructed of cast iron segments bolted together, but it is a very costly procedure and will only be used in exceptional circumstances.

Composite manholes using a combination of materials are also used on occasions.

Benching to manholes should have a fall of 1 in 12 towards the invert



SECTION A-A



PLAN

FIG. 42. Precast concrete manhole.

and be at least as high as the soffit of the outgoing sewer to avoid fouling and to provide a suitable working space for workmen. Step-irons of galvanised malleable cast iron should be built into the manhole walls at 12-in. vertical intervals and staggered 6 in. each side of the centre line

of one of the shaft walls. Where the depth of a manhole exceeds 15 ft, it is preferable to use a galvanised wrought iron ladder.

Where the manhole exceeds 25 ft in depth, rest chambers should be provided at 20-ft intervals with a grated landing platform incorporating a hinged trap-door. Manholes on sewers of 3 ft diameter and over should be provided with safety chains, for fixing across the mouth of the downstream sewer when men are working in the manhole, and with 1½ in. diameter galvanised pipe handrails along the edges of benchings, platforms, etc.

Back-drop Manholes

Where it is required to connect one sewer with another, 6 ft or more below the level of the first, it is advisable to construct a back-drop or tumbling bay type manhole, incorporating a vertical drop pipe. The drop pipe is usually constructed outside the manhole and encased in concrete, with an easy curved junction pipe at its upper end and a cast iron duck-foot bend discharging in the direction of flow at the lower end. The high-level sewer should pass through the manhole wall beyond the junction for rodding and inspection purposes, terminating with a half blank flange. Where the drop pipe exceeds 9 in. diameter, the pipe should be formed of cast iron and some form of water cushion should be provided at the base in the form of a radial junction or stilling pool, to lessen the impact of the falling sewage.

With sewers exceeding 18 in. diameter, it is customary to overcome the drop in level by a ramp or cascade. Similarly, where the difference in level between the sewers is less than 6 ft, it is usual to form a ramp of about 45° with a rodding eye similar to that previously described, as illustrated in Fig. 42.

INVERTED SYPHONS

Inverted syphons are needed to take sewers below rivers and streams, railways in cuttings, etc. where it is impracticable to continue the sewers at their normal gradients. It is essential that the pipes in the syphon should be self-cleansing even with the smallest flows. To accomplish this, 2 or 3 pipes are installed at varying levels, with the additional pipes normally fed over low weirs, to produce velocities up to 4 ft per sec. The pipes will successively come into action as the flow increases, thus the first pipe might take up to 1½ D.W.F. (dry weather flow), the second pipe 1½ to 3 D.W.F. and the third pipe flows in excess of 3 D.W.F.

A typical inverted syphon is shown in Fig. 43 and further examples are illustrated in the Code of Practice (1), the book by Bevan and Rees (4) and the article on the new main sewer at Chelmsford (2).

It is customary to provide penstocks at either end of each pipe, so that they can be isolated for cleaning. In the Chelmsford syphon, the liquid contents of a pipe can be emptied through a sluice valve, with the vacuum destroyed by an air pipe. Access to the pipes is obtained by the removal of hatch box covers in the inner two manholes.

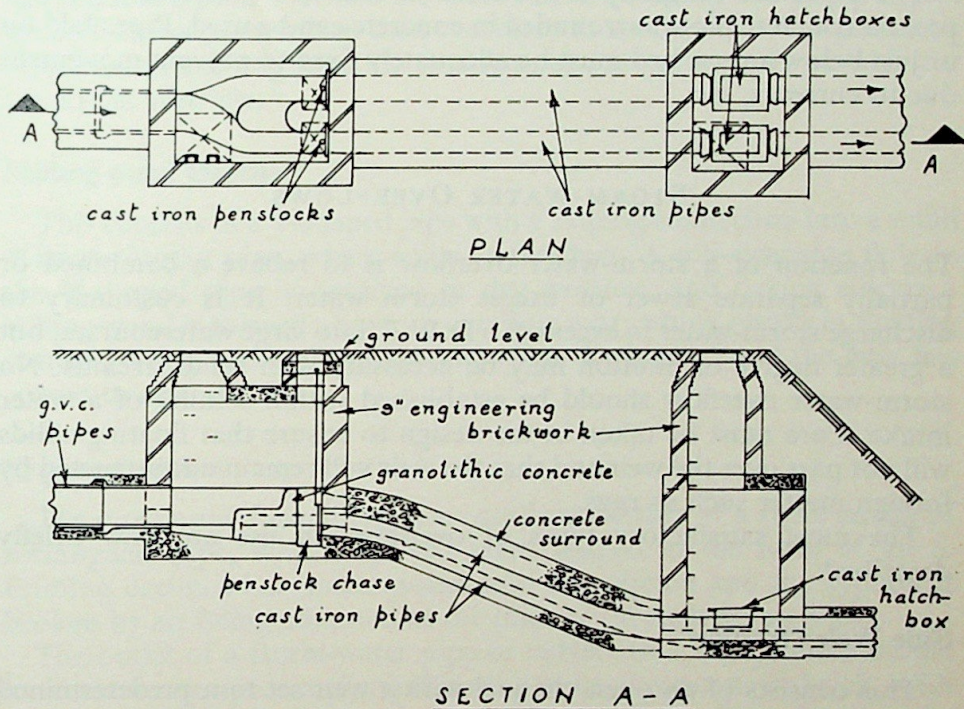


FIG. 43. Inverted syphon.

The optimum gradient for the inclined legs of syphons is 1 in 5, and periodic flushing may be necessary where the velocities obtained are insufficient. The head lost in an inverted syphon can be obtained from the formula

$$H = \frac{4flv^2}{2dg} + \frac{4kv^2}{2g} + \frac{0.5v^2}{2g}$$

where H = head lost in ft
 f = coefficient of friction

- l = length of pipe in ft
- v = velocity in ft per sec
- d = diameter of pipe in ft
- k = constant for bends, often 0.3
- g = acceleration due to gravity (32.2 ft per sec²).

It will be appreciated that an inverted syphon is a pipe operating under pressure, and the operating head is the difference between the water levels of the inlet and outlet to the syphon.

The pipes are normally constructed in cast iron or steel, although precast concrete pipes surrounded in concrete can be used. Pipes laid on or just below a river bed must be adequately fixed to prevent movement due to currents, etc.

STORM-WATER OVERFLOWS

The function of a storm-water overflow is to relieve a combined or partially separate sewer of excess storm water. It is customary to discharge storm-water in excess of 6 D.W.F. into large watercourses, but a greater degree of dilution may be necessary with small streams. No storm-water overflow should be established within 5 miles of a water intake. Care must be taken in the design to ensure that floating solids will not pass over the weir and that the weir will remain unobstructed by foreign matter such as rags.

The most satisfactory types of overflows in use are now briefly described.

Side Weir Overflow

This consists of an open channel with a weir set to a predetermined level on each side; the channel usually reducing in diameter from inlet to outlet to produce a throttling effect. The discharge over the weirs falls into further channels which are linked under the main channel and then lead into a storm-water pipe connected to a watercourse. Dip-plates are fixed vertically in the channel to prevent solid matter passing over the weirs. Curved weirs are sometimes used and these reduce the length of chamber required.

The length of side weir required can be calculated by using Coleman and Smith's formula:

$$L = 0.55wvy_2 \quad 0.13 \left(\frac{1}{\sqrt{y_1}} - \frac{1}{\sqrt{y_2}} \right)$$

- where L = length of single side of weir in ft
 w = width of channel in ft
 v = velocity in sewer immediately upstream of weir in ft per sec
 y_1 = head in ft at downstream end of weir (usually taken as 0.05 ft)
 y_2 = head in ft at upstream end of weir.

Oblique Weir Overflow

With this type of overflow the weir is fixed obliquely across the mouth of the incoming sewer and then continues as a side weir. This permits a reduction in the length of the chamber, and is particularly suitable for use in flat districts.

Stilling-pond Overflow

This consists of a V-shaped pipe with a sloping connection into a small diameter outlet pipe, which controls the flow. A self-cleansing flow in the V-shaped pipe is obtained in dry weather, and during storms a stilling-pond is formed above an overflow weir, which results in floating material being retained until the flow has diminished and the weir has ceased to operate.

Syphon Overflow

The most usual form of syphon overflow consists of a short length of rectangular pipe, with a splayed inlet, shaped in the form of an S. Priming occurs when water passes into the syphon and the syphon is broken by air being admitted at the inlet or through an air-pipe.

The outlet of a storm-water pipe or culvert to a watercourse should have a concrete apron and suitable wing walls of concrete or brick. With narrow streams, it is also advisable to construct a wall on the opposite bank of the stream. It is good practice to provide a bar screen over the outlet to prevent debris and sometimes children gaining access to the pipe or culvert.

TIDAL WATER OUTFALLS

A full investigation must be made of the quantity, character and content of the sewage to be discharged, particularly in the case of tidal estuaries. The times and heights of tides and direction and force of winds must also be considered. The direction of tidal currents will need to be checked

by float observations over a period of 6 to 12 months, and the extent of littoral drift and coast erosion noted.

Following these investigations the probable effect on fisheries and pleasure beaches will become evident and the location and type of outfall, amount of pre-treatment and method and times of discharge can be determined. Storage tanks are often needed, particularly when there are limitations on the periods of discharge from the outfall, and additional capacity is needed for cleansing purposes and ample provision for ventilation. The end of the outfall pipe is normally protected by a self-closing tidal flap.

Outfall pipes are often duplicated to assist the purification process and also the constructional and maintenance work. They may be constructed of a variety of materials including cast iron, steel and concrete pipes. They may be laid in trench on upper reaches of the foreshore, anchored to concrete cradles, anchored through a thin concrete bed to a rocky foreshore or be supported on piles, usually of timber, iron or steel.

For further information on this subject, readers are referred to the papers listed in references 11 to 13 at the end of this chapter.

VENTILATION OF SEWERS

The need for separate ventilation of sewers is very much dependent upon whether or not the sewers are vented through the house drainage systems. With older properties, intercepting traps are usually provided to prevent sewer gas entering the house drains, and in this case sewer ventilating pipes must be provided. With more recent development, it is likely that intercepting traps will be omitted, allowing the free passage of sewer gas through the house drains and up the house ventilating pipes. In the latter case sewer ventilating pipes are not essential. Intercepting traps are best avoided as they frequently give rise to blockages.

From the municipal engineer's point of view, the siting of ventilating columns often creates difficult problems. To be effective they must be located at the heads of sewers and objections are often received from the owners of adjoining properties. They are usually about 25 ft in height and tend to be rather unsightly in appearance. Ventilating columns can be constructed of steel, cast iron, precast concrete or asbestos cement.

PETROL AND OIL INTERCEPTORS

Under the Public Health Act, 1936, no person shall allow any petroleum spirit to enter a public sewer. In this connection, it is desirable that every

garage and premises used for the cleaning and servicing of a considerable number of vehicles, should be provided with a suitable petrol interceptor.

The normal type of petrol interceptor consists of three chambers, each 3 ft × 3 ft × 3 ft deep, constructed of 9-in. brick or concrete walls on a concrete base, with a reinforced concrete cover slab supporting a heavy duty cover to each chamber. The outlet to each chamber consists of a cast iron or vitrified clay bend built into the wall; the bends or dip-pipes to the second and third chambers extend to about 6 in. from the base, whilst the bend in the first chamber terminates about 15 in. from the base to allow for accumulations of grit, etc.

The three chambers allow any petrol present to rise to the surface, evaporate and then escape through 3-in. vent pipes from each chamber into the atmosphere. Any oil will remain on the surface. The outlet from the third chamber is connected to the sewer.

For single private garages, deep gully traps with perforated lifting trays will normally be adequate.

SEWAGE PUMPING STATIONS

In flat and low-lying areas it is often necessary to install pumping stations, from which the sewage is pumped through a pumping main to a sewer at a higher level or a sewage disposal works. Pumping involves high installation and maintenance costs and so it is desirable to reduce the number of pumping stations to a minimum.

When siting pumping stations special attention should be paid to ground conditions, and to the desirability of restricting the length of pumping main (to prevent the sewage becoming septic) and of locating stations as far distant as possible from residential properties.

Standby pumps should be provided, of sufficient capacity to deal with the flow when a pump is out of service. With electrically driven pumps it may be advisable to have standby plant using some other form of power, particularly where serious flooding would otherwise result from electric power failure.

The wet well or sump, in which the sewage is collected, should be of sufficient capacity to prevent a pump continually cutting in and out. At the same time it should not be excessively large or the sewage may become septic.

The design head for a pump consists of static head (including suction lift) and friction head (including losses due to bends, etc). The pump selected must be reliable, durable and easily accessible.

Sewage pumps are of two main types: rotating element pumps and pneumatic ejectors, and each will now be considered.

(1) Pneumatic Ejectors

Ejectors are well suited for discharges below 100 gal/min. The smallest ejector holds 30 gal and ejectors will normally discharge at a maximum

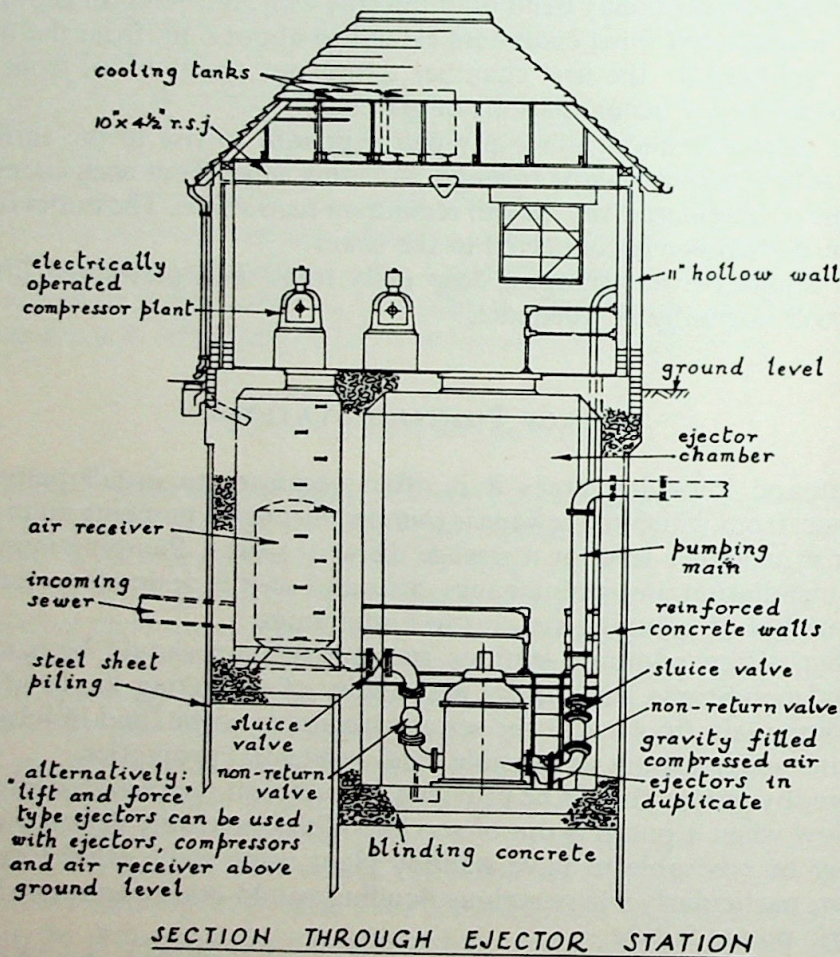


FIG. 44. Pneumatic ejector.

frequency of about once per minute, taking about 10 sec to discharge. They are particularly suited for isolated situations, as they are extremely reliable and easy to maintain.

They usually consist of an automatic self-starting compressor, air

storage and the ejectors. A minimum of two ejectors should always be provided to allow for repairs and it may be advisable to provide a second air compressor. A typical sewage ejector is illustrated in Fig. 44.

(2) Rotating Element Pumps

These pumps are relatively low in cost, of small dimensions and light weight, of reasonably good efficiency and can operate vertically or horizontally.

The most popular type is the centrifugal or turbine-type pump with a vertical spindle. These pumps can be supplied with capacities ranging from 150 to 5,000 gal per min with heads ranging from 20 to 200 ft. Disintegrating centrifugal pumps may be used to break up solids in sewage. Other types of rotating element pump are the mixed-flow pump, for coping with large quantities of sewage, and the propellor or axial-flow pump for pumping large quantities of sewage against a low head.

Prime Movers

A variety of prime movers is available, including the electric motor, internal combustion engine using petrol or oil (or alternatively using town gas, sewage gas or producer gas) and steam engines.

The electric motor is the most commonly used form as it is reliable, convenient and economical, and is particularly suited for use at automatically operated unattended stations. A float-controlled switch is generally operated by the sewage level in the wet well and this actuates the main power control panel. It is desirable to incorporate supplementary manual control in the panel for occasional use.

Pumping Station Construction

The wet well often has a capacity of about 10 min pumping and is generally rectangular in shape. Concrete is the most popular constructional material for this purpose. A thermostatically controlled heating system should be installed to prevent deterioration of electrical gear in motor rooms, etc, and overhead travelling cranes are needed in large pumping stations.

The pumps may be located in a separate dry well, when they have the advantage of ready accessibility, and submerged pumps should only be used as a temporary measure. Pumps may be of the horizontal shaft, vertical shaft or direct-coupled vertically type. In all cases, it is good policy to insert a venturi throat in the rising main from each pump for recording the rates of pumping.

MAINTENANCE OF SEWERS

All sewers must be adequately maintained to ensure that they are kept in satisfactory working order and flowing freely. With pipes under 36 in. diameter inspection can only be made from manholes, whereas with larger sewers the pipes can be traversed, usually during the night when the flow is at a minimum.

Cleaning Sewers of Silt and Obstructions

A special watch must be kept on possible trouble spots, including the vicinity of building sites where debris may enter the sewer through gullies, open manholes, etc.

Sewers should be flushed periodically where they are laid to flat gradients or flows are very small. In the worst cases it is desirable to provide automatic flushing tanks and in other cases gully cleansing vehicles are often used for this purpose, but a penstock valve is needed in each head manhole. Other methods of sewer flushing include high pressure cleaning with a stainless-steel nozzle and pressure hose.

Small blockages can usually be satisfactorily cleared with drain rods, but where there is an accumulation of debris it may be necessary to dredge the pipes by dragging purpose-made buckets, bunches of chains, etc. through the sewer. This tackle is often operated by power winches or crab winches, pulling the tackle downstream. The debris removed from the sewer should be placed in containers with covered tops prior to removing to a tip, to prevent any nuisance arising.

With large sewers small gauge tracks are sometimes laid and the debris removed in trolleys. It assists tremendously if the flow in the sewer can be diverted.

Sewer Repairs

Fractured pipes require replacement and leaking joints need making good. With brick culverts it may be necessary to cut out and renew sections of defective brickwork. It may be necessary to divert the flow with side chutes or small cofferdams in the sewer in lengths up to 30 ft, to enable the repair work to be carried out in the dry.

Older manholes often require repointing and reconstruction of benchings, and step-irons and ladders may need replacement due to severe corrosion. It is often found that the top few courses of brickwork have worked loose due to heavy vibration from traffic. Rocking manhole covers can be remedied by packing with lead-asbestos compound. It is good practice to oil and check all manhole covers once a year, to ensure

that they can be readily lifted as required and are free from road surfacing material.

Infiltration

Infiltration of sub-soil water into the sewerage system can be checked by recording early morning flows by one of a number of methods. V-notches, rectangular notches and circular pipe weirs have been used on occasions, but probably the best results are obtained with a trapezoidal flume. Chemical recording methods are also suitable using the 'gulp' or chemical dilution methods (5). Bad points of leakage can be located by drawing an inflated rubber bag through the sewer from manhole to manhole with cord, which is first floated through the length of sewer.

Safety of Workmen in Sewers

Maximum safety precautions must be taken to safeguard workmen engaged in the maintenance of sewers. The provision of handrails and chains in manholes, to prevent men being swept away by sudden large flows of sewage, and rest chambers on deep manholes, have already been mentioned.

Concentration of certain gases in sewers can make respiration difficult and in extreme cases be poisonous or cause explosions. Tests should be made prior to men entering sewers to ensure that conditions are satisfactory. Before a man enters a manhole, the cover of this manhole and the adjoining manholes should have been removed $\frac{1}{2}$ hr previously to ventilate the sewer.

Tests should be made with moistened lead acetate paper to detect any hydrogen sulphide, with a safety lamp for asphyxiating conditions and with a suitable detector lamp for inflammable gases. The man entering the sewer should wear a lifeline and two men should be posted at the entry manhole and adjoining manholes kept open. No smoking or naked lights can be permitted in the sewer.

The workmen engaged on sewer work should be well instructed in safety precautions and each travelling sewer gang should carry a suitable rescue kit (6) and (7).

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CHAPTER SIX

Sewage Disposal

THE bulk of sewage receives some form of treatment before it is discharged into a watercourse, a river or the sea. The size and scope of sewage treatment plants vary tremendously, from the small septic-tank installations serving half a dozen rural houses to the two gigantic outfall works dealing with the whole of London's drainage.

The primary function of sewage purification plant is to render the sewage relatively harmless prior to discharge into natural watercourses. Polluted watercourses can be a potential danger to public health as well as being injurious to fish life. Since June 1963, the River Boards have had wide powers of control of the discharge of effluents into watercourses under the Rivers (Prevention of Pollution) Act, 1961.

PRINCIPAL METHODS OF PURIFICATION

Small domestic sewage disposal plants are dealt with in some detail later in this chapter. The usual pattern of the works serving small to medium-sized towns consists basically of the following component parts:

- (1) Screens to remove foreign matter, such as rags, pieces of wood, etc.
- (2) Detritus channels where the sand and grit suspended in the sewage are deposited.
- (3) Sedimentation tanks where a high proportion of settleable solids is precipitated.
- (4) Storm water tanks for dealing with storm flows.
- (5) Biological plant such as percolating filters or aeration plant, wherein beneficial bacteria break up and absorb the noxious elements.

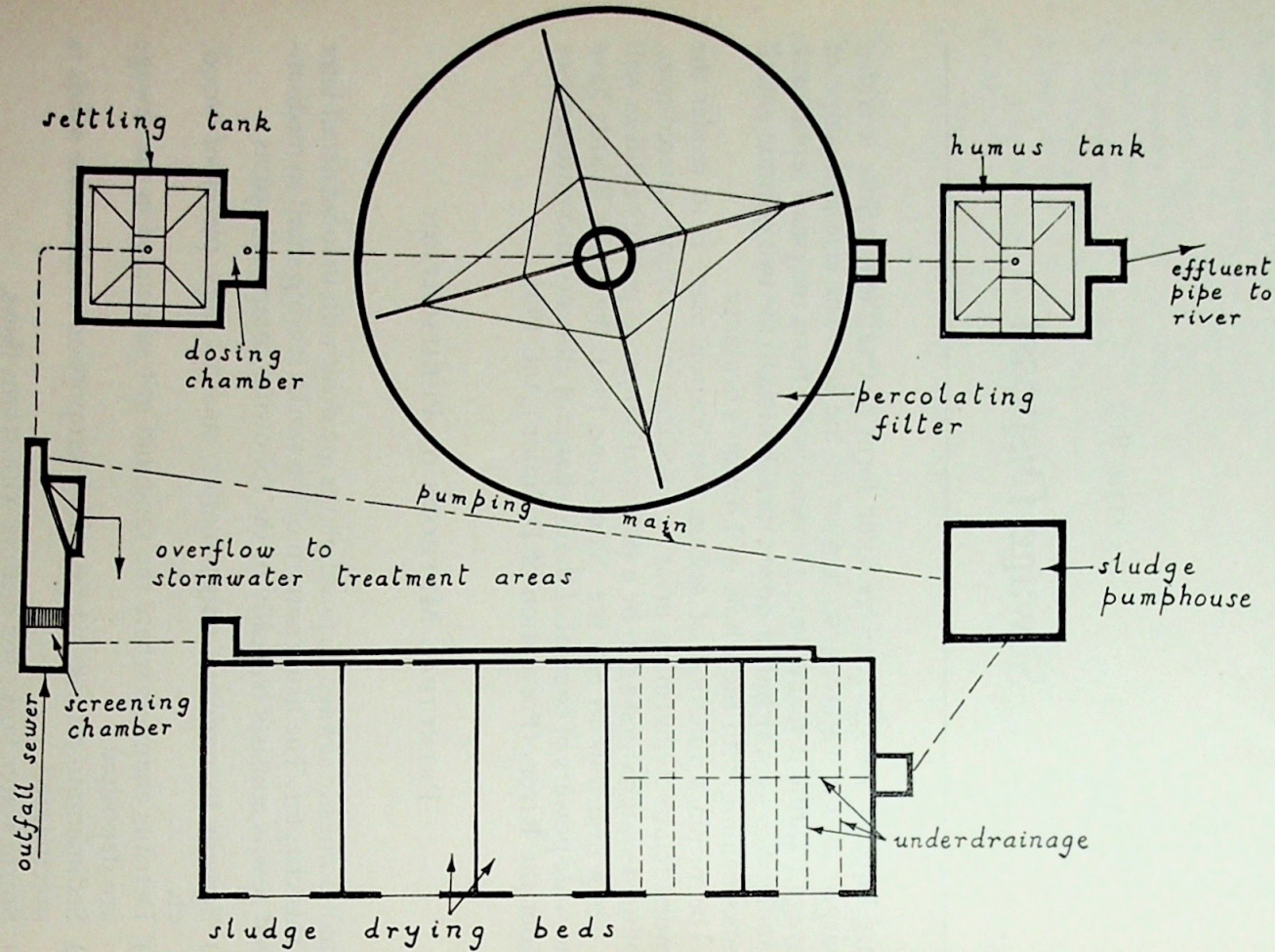


FIG. 45. Layout plan of sewage disposal works.

- (6) Humus tanks or other plant to remove residual suspended solids.
- (7) Sludge processing plant for dealing with solids precipitated in the various tanks.

Each of these subsidiary processes will be considered later in this chapter. Fig. 45 shows a layout plan for a sewage treatment plant to deal with the sewage from about 700 persons.

STANDARDS OF PURIFICATION

The strength of sewage is usually determined by one of the following methods:

- (1) Obtain McGowan strength figure by using the formula:
 $4.5 (\text{ammoniacal nitrogen} + \text{organic nitrogen}) + 6.5 (N/8 \text{ permanganate value})$, all in parts per 100,000, where $N/8$ permanganate value is the oxygen absorbed in 4 hr at 27°C.
- (2) Five-day B.O.D. (biochemical oxygen demand) in which a sample of the sewage is incubated for 5 days at 20°C and the oxygen absorbed by the liquid is recorded in parts per million (p.p.m.). This test is based on the fact that when polluting organic matter is discharged into a watercourse a natural purifying process takes place, due to the action of certain micro-organisms which utilise the atmospheric oxygen dissolved in the water to oxidise the polluting substances.

The Royal Commission on Sewage Disposal prepared three classifications for the strength of sewage (see reference 1 at the end of this chapter).

<i>Classification</i>	<i>McGowan strength</i>	<i>5-day B.O.D. (p.p.m.)</i>	<i>N/8 permanganate value (4-hour)</i>
Weak	60	210	7—8
Average	100	350	10—12
Strong	160 and over	500	17—25

After treatment, a sewage effluent should not contain more than 30 parts per million of suspended solids or have a B.O.D. value in excess of 20, in order to be of a satisfactory standard and to satisfy the Royal Commission requirements. Where the dilution of the effluent exceeds 150 times, a greater proportion of suspended solids is usually permitted.

Another common requirement for a good effluent is that the B.O.D. value of the watercourse after receiving the effluent should not exceed

4 parts per million. This value can be obtained from the following formula devised by the Royal Commission:

$$\text{B.O.D.}_m = \frac{x + yz}{z + 1}$$

where B.O.D._m = B.O.D. of mixed effluent and river water

x = B.O.D. of effluent

y = B.O.D. of river water above outfall

z = rate of dilution (river/effluent).

The nitrates in sewage effluent should exceed 5 p.p.m., showing efficient oxidation and stability, but may not be present where aeration processes are used. Nitrites should be less than 1 p.p.m.

There are a number of visual tests which can be undertaken on sewage effluent of which the commonest are:

- (1) Shaking for 1 min after which all frothing should disappear in less than 3 sec.
- (2) Odour—none.
- (3) Colour—none.
- (4) Opacity—ability to read standard print through a column of effluent 12 in. in height.

A number of approximate methods of analysis suitable for effluents from small sewage works are described in *Chemical Analysis as Applied to Sewage and Sewage Effluents* (2).

COASTAL POLLUTION

Many coastal towns discharge untreated or partially treated sewage from outfalls located only a short distance below low water level. In some cases this has resulted in visible pollution and some public concern. Medical authorities have investigated the situation and are generally satisfied that there is no risk to public health from bathing on polluted beaches (3).

Nevertheless, it is obviously most desirable to treat the sewage or improve the outfalls in order to prevent the visible contamination of beaches. The Water Pollution Research Laboratory are conducting investigations into this and many other aspects of sewage effluents, and have already determined that there is a rapid dilution as the effluent rises to the surface and then further quite rapid mixing as it is carried away from the outfall by tidal and wind-induced currents (4). In one case,

screening followed by the discharge of macerated screenings at a suitable state of tide eliminated visible pollution (5).

Some coastal authorities have lengthened or relocated their outfalls, others have adopted conventional methods of treatment and a few are considering electrolytic techniques, which have been the subject of considerable research in Scandinavia and Naples.

SCREENING OR DISINTEGRATION

The initial preliminary treatment of the sewage at a purification works normally consists of screens to remove the larger or coarser solid matter, or disintegrators or comminutors which reduce the solids to small particles without removal from the flow of sewage. A further alternative is a combination of the two processes, as carried out at the London out-fall works, where the sewage is passed through screens and the solids mechanically raked off the screens, passed through disintegrators and returned to the flow.

In the smaller works, mechanically raked screens are not usually economical and manually raked screens are liable to become clogged during periods when the works are unattended. In these circumstances the use of disintegrators or comminutors to break up the solids has much in its favour, as they require little attention (6).

The disintegrator is a power-driven vertical trommel screen with a series of cutters which rotate about a vertical axis and disintegrate the solids passing through it. The only materials rejected are indestructible solids such as stones. Comminutors were installed at the Maple Lodge Works of the West Hertfordshire Main Drainage Authority (design population—432,000 and present population served about 480,000) in preference to the use of screens, raking mechanism, belt conveyor and macerator, with a consequent reduction in aerial and visible nuisance (7).

Screens are produced to a variety of patterns. The most common form consists of a series of diagonally fixed steel bars about $\frac{1}{2}$ in. wide and spaced $\frac{1}{2}$ in. to $\frac{3}{4}$ in. apart. A rake, preferably mechanically operated, slides up the bars at intervals and discharges the screenings into a collecting channel. The quantity of screenings is usually about $\frac{3}{4}$ ft³ per day per 1,000 population served. In small works the screenings, which can be very offensive, are often trenched into the ground. In larger works the screenings may pass along a conveyor belt into a washer which sorts the screenings, returning all faecal and similar matters for further treatment, whilst the rags, stones, pieces of wood, etc. are washed and discharged from the plant in a clean and relatively dry condition.

Mechanical rakes can operate in a number of ways:

- (1) Control by a time switch whereby the screen bars are cleared at prearranged intervals.
- (2) Control by a differential level switch either independently or in conjunction with the time switch (controlled by difference in water level on each side of the screen).
- (3) Control by a time switch in conjunction with a single level switch located upstream of the screen bars, bringing the rake into operation when the maximum water level is reached due to clogging of the screen.

In some works a hand-raked screen is provided as a standby in the event of a breakdown of the mechanically raked screen.

In very small works horizontal hinged screens are sometimes employed whereby the sewage enters below the screen and flows upwards through it. Solids are trapped below the bars of the screen and settle into the hopper-shaped bottom of the tank. A ball valve at the bottom is raised periodically to empty the solids into sludge lagoons.

In deep channels, grab type screens are often introduced with vertical screen bars at the bottom of the channel, with an automatically controlled travelling rake carriage supported by vertical chains from head-gear above ground.

GRIT REMOVAL

When sewage flows along a channel at a velocity of about 1 ft per sec grit and sand will settle at the bottom of the channel, whilst the organic solids will be carried forward with the sewage for subsequent treatment. It is, therefore, very important that grit or detritus channels should be so designed that the velocity of the sewage is constant at all rates of flow.

Grit channels are usually V-shaped or parabolic in cross section and the depths of flow are controlled by standing wave flumes, which are also often used as flow-measuring flumes. In a large works the channels can usually be isolated for grit removal and can be arranged to come into operation successively in any predetermined order.

Various types of grit extractor are available—from the submersible centrifugal pumps on travelling bridges in the very largest works to the rotating scrapers mounted on light-wheeled carriages, which may be hand or power operated, for use in smaller works. In very small works the grit may be shovelled out of the channels by hand.

Messrs Ames Crosta Mills have designed a vortex grit plant, in which

the sewage enters tangentially into a circular tank. Mechanically driven paddles are operated in the tank to produce gentle vortex conditions at all rates of flow, allowing the grit to settle but keeping the majority of the organic matters in suspension. The settled grit is removed from the hopper bottom of the tank by an air lift pump and delivered to a vortex grit washer to clean the grit and separate any organic matters from it.

SEDIMENTATION TANKS

Flows up to 3 or 4 D.W.F. (dry weather flow) normally pass through the sedimentation tanks and receive full treatment. Excess flows are diverted to storm-water tanks for partial treatment. In the smaller works the excess flow passes over a long weir fixed parallel with the direction of flow. In very large works, as at the Maple Lodge works of the West Hertfordshire Main Drainage Authority (7), the flow is controlled within more accurate limits, by means of a motor operated penstock controlled by a 'Noflote' system working from the level of the flow immediately upstream of the 3 D.W.F. flume.

Sedimentation or settling tanks are used to settle out the lighter suspended solids. In older works most of these tanks are rectangular in shape with a horizontal flow and sloping bottom falling to the sludge outlet and involving manual desludging with squeegees. The majority of sedimentation tanks on the larger modern works are circular in shape with their bottoms sloping slightly towards a central sludge hopper, as illustrated in Fig. 46. The sewage enters the lower part of the tank, often through a dispersion drum in the centre of the tank, from which it flows both radially and upwards to discharge under a scum plate over a peripheral weir into an effluent channel running around the tank.

A mechanical scraper with rubber tipped blades revolves from a central vertical shaft and forces the sludge from the bottom of the tank into the central hopper, from whence the sludge is periodically drawn off under hydrostatic head. The scraper often incorporates a scum skimming device for removal of scum at intervals. A platform with handrails is usually provided across the centre of the tank to give ready access to lubricating points.

The smaller works have tanks ranging from 30 ft to 65 ft in diameter with a fixed bridge, whilst the diameters of tanks on the larger works may range from 50 ft to 200 ft and they have rotating bridges. The normal retention period of sewage in a primary sedimentation tank is $1\frac{1}{2}$ to 2 hr (maximum flow). The depth of a sedimentation tank should never be less than 6 ft and is usually between $\frac{1}{3}$ and $\frac{1}{10}$ of the diameter. Some

engineers favour the use of pyramidal tanks in works serving populations of say 500 to 10,000 or more. These tanks with hopper shaped bottoms do not require mechanical scrapers and the sludge is discharged under hydrostatic head. It is sometimes found, in practice, that these tanks are more costly than the simpler circular shallower tanks with mechanical scrapers. Other engineers favour compromise designs (6). Pyramidal tanks often have a capacity of 8 to 10 hr D.W.F. and maximum vertical flows of $3\frac{1}{2}$ to $4\frac{1}{2}$ ft per hour.

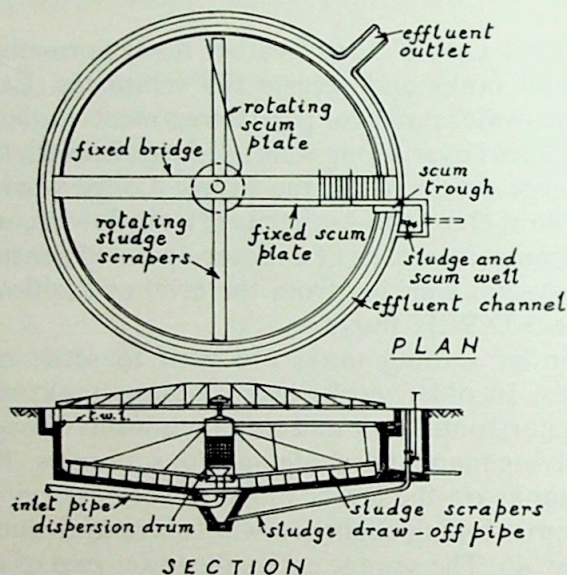


FIG. 46. 'Simplex' circular settling tank.

Rectangular sedimentation tanks with scum boards at either end, weir outlet and bottom sloping towards the sludge sump at the inlet end are still constructed in some small treatment works, largely on the grounds of lower construction costs and shallower and simpler excavation work. Rectangular sedimentation tanks were provided on the West Hertfordshire Main Drainage Scheme, 272 ft long by 52 ft wide and of 10 ft mean water depth. All the tanks are arranged in a single battery side by side and with common walls. This design is economical in space and construction and the tanks can be scraped by a common scraper or pair of scrapers. A common outlet channel serves both sedimentation and storm-water tanks and the latter can be converted to the former by altering inlet penstocks, should subsequent adjustment prove desirable (7).

It is desirable to make all circular sedimentation, storm-water and

humus tanks of the same diameter, to keep constructional costs to a minimum and to ensure the maximum use of formwork.

STORM-WATER TANKS

These tanks are usually of similar construction to the sedimentation or settling tanks. They usually receive flows in excess of 3 or 4 D.W.F., which pass slowly through the tanks permitting the settling out of lighter suspended solids, and which are then discharged direct into a river or other watercourse.

It is good practice to fill one tank first so that the other tanks will not be fouled after a short storm. This tank should not have an outlet weir so that the first flow of storm-sewage will be retained in the tank, as this first flow often contains a high proportion of sludge scoured from the sewers, particularly when a dry period terminates in a heavy storm.

When the flow through the sewage works has returned to normal, the storm-sewage in the storm-water tanks should be returned to the sedimentation tanks for full treatment and the sludge pumped to sludge digestion tanks or beds.

PERCOLATING FILTERS

Following sedimentation, the next stage in the purification process is mainly a choice between percolating filters and bio-aeration, designed to break down the dissolved impurities in the sewage by rapid oxidation. This is a biological process in which bacteria and similar organisms effect the change.

Numerous types of plant and animal life are found in percolating filter media. Of the plant life probably the most important are aerobic bacteria, which only thrive in the presence of oxygen and include various types, each of which consume different organic or inorganic compounds from the sewage. Other plant life found on percolating filters include certain types of fungi and algae which tend to form a coating over the surface of the media and can have a clogging effect.

The animal organisms include many of the lower forms of animal life which feed upon bacteria, organic matter on the surface of the media, etc. One of the commonest varieties are bristle worms (*oligochaeta*), which pass the filter film through their bodies and discharge it in a form which can readily be carried away as humus.

Of the insects found on percolating filters the most common are

achorutes viaticus (bluish-grey wingless insects of the springtail variety) which perform a useful function by feeding on the filter film, and *psychoda alternata* (two-winged insects) which feed upon the filter film at the larva stage, but later constitute a nuisance as small grey moth-like flies which appear in large numbers in spring and summer. The number of flies can be reduced to manageable proportions by applying monthly 5 to 10 lb of D.D.T. or 1 lb of Gammaxene per acre of filter surface.

Percolating filters are particularly popular for use in smaller treatment works where adequate fall is available. They are normally constructed of brick or concrete walls on a concrete base supporting perforated floor tiles. The floor tiles support the filter media and permit the filter effluent to drain through into a series of channels beneath.

The filter media generally consists of the most suitable local material, such as clinker, limestone, slag or granite; often graded from 1 in. to 4 in. in size. A common depth of filter is 6 ft and they are frequently circular in shape, as although these are more expensive to construct they require no power to operate. A typical filter capacity is 60 gal D.W.F. per yd³ of media. A typical filter of this type is illustrated in Fig. 47.

The sewage is fed on to the filter through a dosing syphon in a small dosing chamber, which starts to operate when the sewage reaches a certain level and cuts out when the chamber is emptied. The sewage then passes through a feed pipe, central revolving pillar with ball-bearing guide rollers and a mercury seal, and thence through distributing arms on to the surface of the filter media. The distributing arms have removable end caps for cleaning purposes and the outlets are usually formed with copper ferrules or gunmetal or plastic screwed bushes. An efficient sprinkler must be capable of revolving under a head of 2 or 3 in. under all weather conditions and give an even distribution of settled sewage over the surface of the filter, which may be up to 110 ft in diameter.

With rectangular filters, the settled sewage is usually fed into open distribution troughs of concrete or steel located in the centre of each bed. A rail track, which carries a wheeled receptacle with distributing arms cantilevered from either side, is normally laid along the walls of the trough. A syphon is used to feed the sewage to the distributing arms from the trough and the wheeled receptacle is driven either by waterwheels actuated by the sewage flow or by an electric motor.

Various filtering arrangements have been introduced to enable percolating filters to deal with larger flows or to produce a higher standard of effluent with the same flows. The principal methods that have been employed are the normal single-pass treatment, recirculation and alternating double-filtration.

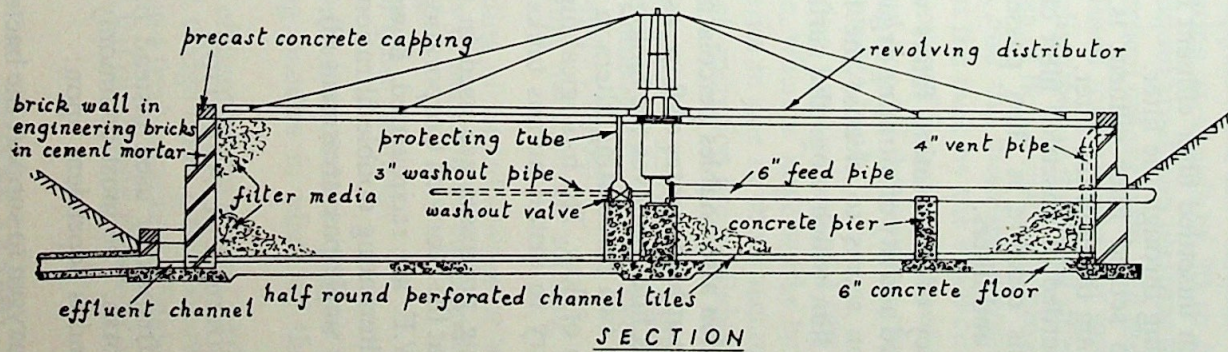


FIG. 47. Percolating filter.

Recirculation consists of returning part of the filter effluent and mixing it with the sewage to be treated by the filter. Three main systems of recirculation have been used in the United States, namely:

- (1) Accelo filter, in which unsettled filter effluent is mixed with settled sewage prior to passing through the filter.
- (2) Aero-filter, in which settled filter effluent is mixed with settled sewage prior to passing through the filter.
- (3) Bio-filter, in which settled or unsettled filter effluent is mixed with raw sewage and this mixture is then passed through primary sedimentation tanks and filters.

The increased efficiency of percolating filters with recirculation is largely due to the increased activity of nitrating organisms. In particular, this method of operation seems to cleanse the filtering medium by removing the biological film which clogs the surface of the filter and gives rise to ponding.

Alternating Double-filtration also enables percolating filters to satisfactorily treat settled sewage at higher rates of flow, as the application of a nitrated filter effluent to a filter removes the biological film. The settled sewage is passed through two percolating filters in series, with periodic variation in the direction of flow. The biological film is washed away as humus and it is necessary to install humus tanks after each stage of filtration.

All three main filtering processes are used in the same works on occasions. For instance, at the Norwich Corporation works at Whitlingham, flows up to $\frac{1}{2}$ D.W.F. are recirculated, flows between $\frac{1}{2}$ and $1\frac{1}{2}$ D.W.F. are subject to alternating double-filtration and flows between $1\frac{1}{2}$ and 3 D.W.F. receive single-pass treatment (8).

BIOLOGICAL AERATION

Aeration processes are frequently used instead of percolating filters, particularly on larger works. The most commonly used method introduces activated sludge and is dependent upon:

- (1) An ample supply of oxygen to support the bacteriological processes.
- (2) Adequate circulation of the tank contents to achieve thorough mixing of the activated sludge and sewage, to prevent the deposition of sludge and silt.

Tank capacities are usually in the order of 6 to 12 hr D.W.F. depending on the process used.

A suitable type of apparatus is the 'Simplex' aerating cone of specially shaped blades operating at speeds of 30 to 50 rev per min, whereby heavy discharges of liquid are drawn up from the bottom of the aeration channel through a vertical uptake tube, and then pour over the lip of the cone in a heavy diffused torrent onto the surface of the liquid in the channel. A vigorous disturbance is created spreading outwards in waves, a much increased area of liquid surface is brought into contact with the atmospheric oxygen and the dissolved oxygen is speedily and evenly dispersed throughout the tank by the rapid circulation of the liquid. In fact a complete turn-over of liquid is obtained about every five minutes, scouring the walls and floor of the aeration channel and preventing any settlement of silt or sludge banks.

Small plants, serving populations of 1,000 to 3,500, incorporate a single tank and cone, whereas large works have a number of aerating cones arranged in series in one or more rectangular aeration channels.

Various methods of operation are available, such as:

- (1) Normal 'through-flow' activated sludge treatment, whereby settled sewage immediately meets returned activated sludge on entering the aeration channel.
- (2) The use of varying numbers of aerating cones for sludge reconditioning.
- (3) Incremental feeding of settled sewage or 'stepped aeration'.
- (4) Tapered intensity of aeration by adjustment of lineshaft speeds and cone immersions.
- (5) Combinations of these methods.

Other aeration systems introduce diffuser plates, rotating brushes and slowly revolving paddles in place of the cones previously described.

The aeration tank effluent passes to final settling tanks where separation of the activated sludge takes place, following which it is returned to the aeration plant in a fresh condition. Final settling tanks are usually circular in plan with flat or sloping floors with mechanical scrapers.

HUMUS TANKS

Humus tanks are invariably located after percolating filters to intercept the dark brown fungus-like solids which are contained in the filter

effluent. The majority of humus tanks are of the upward-flow variety to ease sludge removal and are similar in construction to sedimentation tanks.

Typical retention periods or tank capacities vary from 4 to 5 hr D.W.F. with maximum upward velocities ranging from $4\frac{1}{2}$ to 7 ft per hr. It is good practice to install a sampling chamber beyond the humus tanks for taking samples of the final effluent.

FINAL TREATMENT OF EFFLUENT

Further treatment is often advisable to reduce the concentration of organic suspended matter in sewage effluents to a level below that which can normally be achieved by sedimentation. The principal methods available are land irrigation, where sufficient land is available, but more probably micro-strainers or rapid sand filters. This treatment is often referred to as 'final polishing' of the effluent and may be limited to part only of the flow. The cost of this tertiary treatment is high but its provision may be a requirement of the River Authority.

The Water Pollution Research Laboratory is carrying out investigations into the different methods of treatment (9).

Land Irrigation

Surface irrigation is still used as a method of sewage treatment in a number of small rural works and as a final polishing process in some larger works. It is essential that a suitable area of ground of even contour is available. The effluent is spread evenly over the surface of the ground from distributing channels running with the contours at the top of the slope. The flow should be sufficient to give a minimum depth of $\frac{1}{16}$ in. over the entire weir length and a collecting chamber, possibly incorporating a tipper bucket may be necessary on very small works to achieve this.

A collecting channel, usually constructed in *in situ* concrete or half-round pipes, picks up the effluent from the irrigation area, from which it is piped to the nearest watercourse. The distributing channels are usually fitted with handstops at intervals to allow flows to be discharged alternately over different areas, so that part of the area is 'resting'. The area of land required will vary with the composition and porosity of the soil and the extent of other treatment of the sewage.

SLUDGE TREATMENT AND DISPOSAL

The term 'sludge' refers to the solid matter deposited at the bottoms of sedimentation, storm-water and humus tanks. Sludge does possess a very high moisture content and the treatment and disposal of this material is probably the most difficult problem in sewage purification work.

Not all types of sludge have the same characteristics. For instance, surplus activated sludge retains a higher moisture content and needs special treatment. Humus sludge is often pumped back to the inlet of the works and allowed to settle with the raw sludge.

A variety of methods of treatment of sewage sludge are available and these will now be considered.

Drying Beds

Drying beds consist of a level layer of clinker or ash, usually about 12 to 18 in. in thickness and surrounded with earth banks or concrete walls, with underdrainage discharging at the works inlet, often consisting of porous pipes laid in herringbone pattern. For this reason it is generally necessary to pump the sludge onto the drying beds.

The capacity of drying beds is generally taken at 4 to 5 persons per yd², and so they are not usually a practicable proposition for works serving populations in excess of about 3,000, unless used in conjunction with digestion tanks, due to the large area of land required. Other disadvantages include the adverse effects of variable weather conditions and shortage of labour for operational purposes.

Much improved methods have been evolved in recent years for removal of the dried sludge from the drying beds. These include continuous belts discharging into vehicles, monorail equipment and the construction of beds so as to permit the use of mechanical barrows or dumpers without damaging the under-drains. Yet another method uses beds with level concrete floors, suitably channelled for drainage purposes, with wedge wire fixed $\frac{1}{2}$ in. above the floor. Water is passed onto the bed followed by sludge, and the water is then slowly drained off leaving the sludge supported by the wedge wire and the flow of air beneath it assists the drying process.

Digestion Tanks

For works serving populations in excess of about 3,000 it is advisable to consider the provision of digestion tanks. The moisture content, and hence the volume of the sludge, is reduced considerably by the action of

anaerobic bacteria working in the fermenting sludge in the digestion tanks and causing a breakdown of the solid matter. This process is normally carried out in two tanks in series and heated tanks are not usually introduced in works serving less than about 50,000 population.

The main advantages of the 'cold digestion' process are that the quantity of sludge is reduced, the smell is inoffensive, the sludge is dewatered more easily and the digested sludge is in greater demand as it has a higher manurial value than normal sludge. It is also possible to collect, store and use the sludge gas arising from the sludge digestion process. This consists mainly of methane and carbon dioxide, and can amount to about 0.8 ft^3 per head per day, with a net calorific value of 580 to 650 B.Th.U. per ft^3 . On large works the gas is often used in engines to generate power and the circulating water from the engines is used to maintain the temperature of the digesting sludge. Digested sludge dries quite readily and can often be removed from drying beds after 10 to 14 days.

Heated sludge digestion can be performed in one of two ways:

- (1) Using a heated primary tank with a fixed roof of steel or concrete and an open secondary storage tank. Crude sewage enters the tank below the surface of the sludge and the gas collected by the roof maintains the sludge at digestion temperature. The contents of the tank are mechanically mixed, and as crude sludge enters the primary tank digested sludge is discharged into the secondary tank, where it is stored preparatory to being passed onto drying beds.
- (2) The larger works often use a single-stage plant of circular tanks with floating roofs. For example, the largest 'Simplex' floating roof type digestion tank has a diameter of 65 ft and can serve a population of 100,000. With this plant the crude sludge is pumped daily into the digestion tank and the floating roof rises to accommodate it, and it is intimately mixed with the actively digesting sludge by a screw pump at the top of a central vertical uptake tube. Digestion temperature is maintained by a sludge heater and digested sludge is drawn-off as required from the quiescent consolidation zone, in the hopper-shaped bottom of the tank, and discharged directly onto drying beds.

Heated digestion tanks usually have a capacity of about $1\frac{1}{4} \text{ ft}^3$ per head for primary tank sludge, rising to 2 ft^3 per head for primary plus activated sludge.

Vacuum Filtration

This process operates on the principle that a partial vacuum is applied to one side of the filtering screen, while the mixture to be filtered is kept

on the other. The sludge forms a thin cake on the filtering screen and is continuously removed. The filter may be of the drum or disc variety.

The lower sections of the plant are immersed in the raw sludge and an internal vacuum draws liquor into the drum or discs and a thin cake of dewatered sludge is retained on the filter cloth. The drum revolves slowly and the sludge cake is then released by internal air pressure and removed on a conveyor belt.

The main advantages are the speed of operation, small space requirements and that it can operate independent of the weather. On the other hand, the operating costs are high with the need for skilled operatives and costly chemicals for conditioning purposes. Iron and aluminium salts and lanthanides have been used, but probably copperas with lime is the cheapest chemical for conditioning crude sludges, in order to coagulate the sludge particles prior to filtration.

At the Maple Lodge Sewage Disposal Works, it was decided to remove (by elutriation) some of the substances dissolved in the liquid content of digested sludge which have a chemical affinity for some of the conditioning chemicals, such as ferric chloride, to reduce the amount of the latter required (7). At this Works, digestion of primary sludge is carried out to produce sludge gas for generating power, followed by vacuum filtration, flash drying and incineration.

The filter cake still has a moisture content of 75 to 80 per cent and so it is mixed with a quantity of previously dried sludge in a 'pug-mill' type paddle mixer and then dried in a 'flash dryer', with furnace gases at a temperature of about 1,300°F, ready for fertiliser production.

Composting Sludge with Town Refuse

There seems little doubt that some towns could treat part of their sewage sludge with town refuse in a suitably designed composting plant, provided their refuse had a suitable compostible content. The sewage sludge helps to reduce the carbon/nitrogen ratio and so produce a useful product for agricultural and horticultural purposes (10).

This particular aspect will be considered in more detail under refuse disposal in Chapter VII.

Disposal of Sludge

The most common method of disposal of sewage sludge has been to farmers as fertiliser. Filter press cake, with a moisture content of about 40 per cent and a good lime content, is quite attractive to farmers and smallholders. Unfortunately, farmers only require the sludge at two short seasons of the year, and so it may become necessary to provide

storage facilities and sufficient vehicles for transportation when required. With small works farmers and allotment holders can often be encouraged to cart the sludge away from the sewage disposal works, provided that satisfactory access is available. At the Maple Lodge Works of the West Hertfordshire Main Drainage Authority, the whole of the digested sludge is disposed of either via the drying beds or by cartage in liquid state in tankers to farms in the locality for use as fertiliser.

Coastal towns and towns situated on tidal estuaries often dispose of sewage sludge by sea. For instance, the Greater London Council operate a fleet of four sludge vessels, each of approximately 1,500 tons capacity, which take the sludge 55 miles from the Northern and Southern Outfall Works to the Black Deep, where the sludge is deposited in the depths of the sea.

LAYOUT OF SEWAGE DISPOSAL WORKS

The method of operation of a very large modern sewage disposal works is shown in the flow diagram (Fig. 48) and layout plan (Fig. 49), relating to the Maple Lodge Works of the West Hertfordshire Main Drainage Authority. The drainage area of this Works, includes St Albans, Elstree, Potters Bar, Hemel Hempstead, Watford, Bushey, Chorleywood and Rickmansworth. The grit channels have recently been superseded by detritors (keeping the original channels for standby use) and the final effluent is now discharged into the Grand Union Canal.

An illustration of a modern sewage disposal works, to serve 2,400 population, is shown in Plate VI. The works consist of a measuring flume, pumping station, screen chambers, upward flow sedimentation tanks, percolating filters, horizontal flow humus tanks, sludge digestion tanks and sludge drying beds.

Medium-sized works have been considered in some detail in this chapter. At the other end of the scale are a multitude of very small works serving populations of under 10 up to several hundreds. These installations principally consist of a septic tank and biological filter from which the effluent often discharges, with or without a humus tank, into a nearby watercourse. River Authorities do not favour discharges into watercourses in this way and usually prefer some form of land irrigation, where the soil is sufficiently porous.

A considerable amount of valuable information on the design of small domestic sewage treatment works is given in the Code of Practice (11) and a Ministry Memorandum (12). The Ministry recommendations as to siting of works and tank and filter capacities are rather less exacting

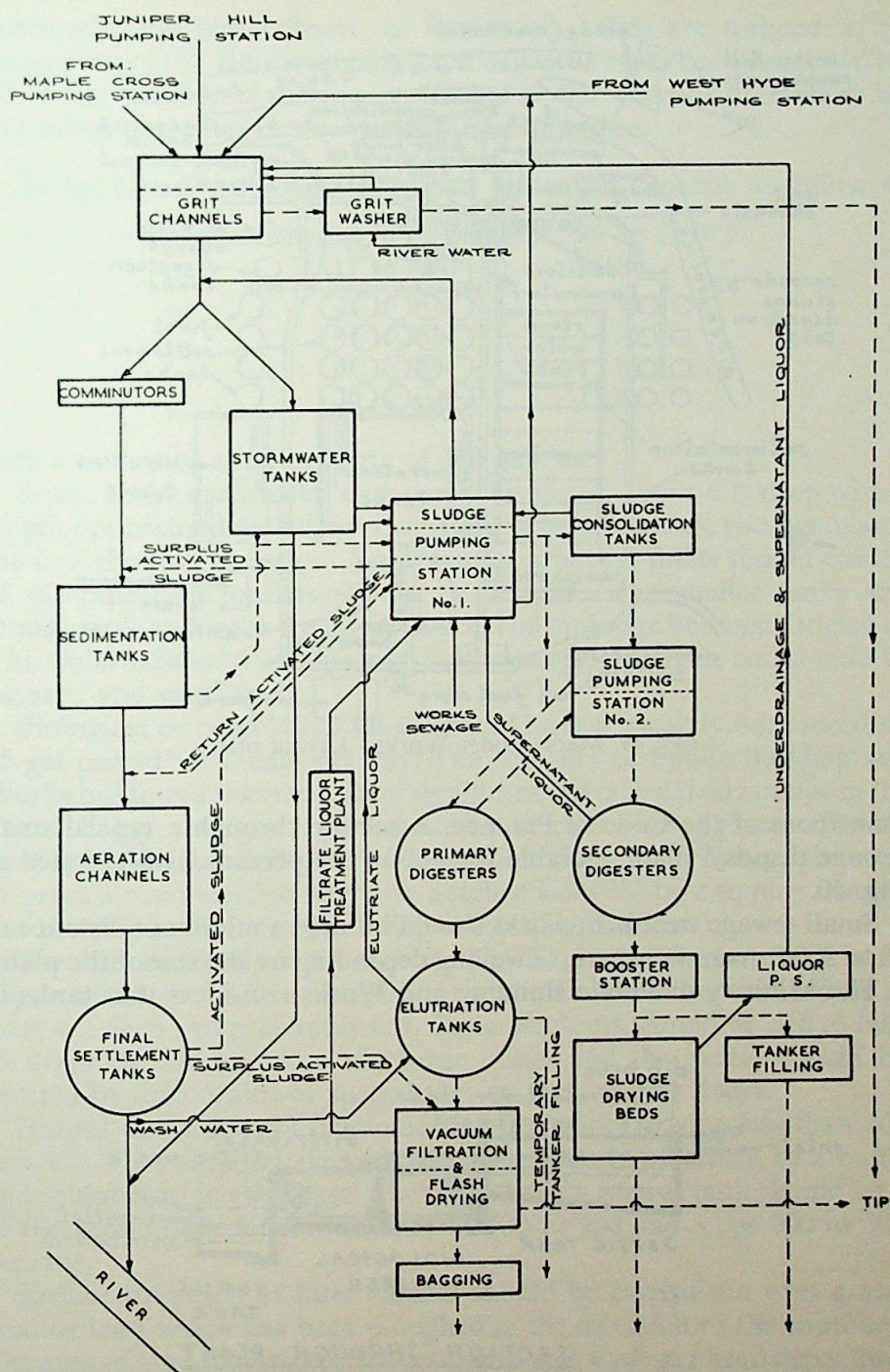


FIG. 48. Maple Lodge Works—Flow diagram.

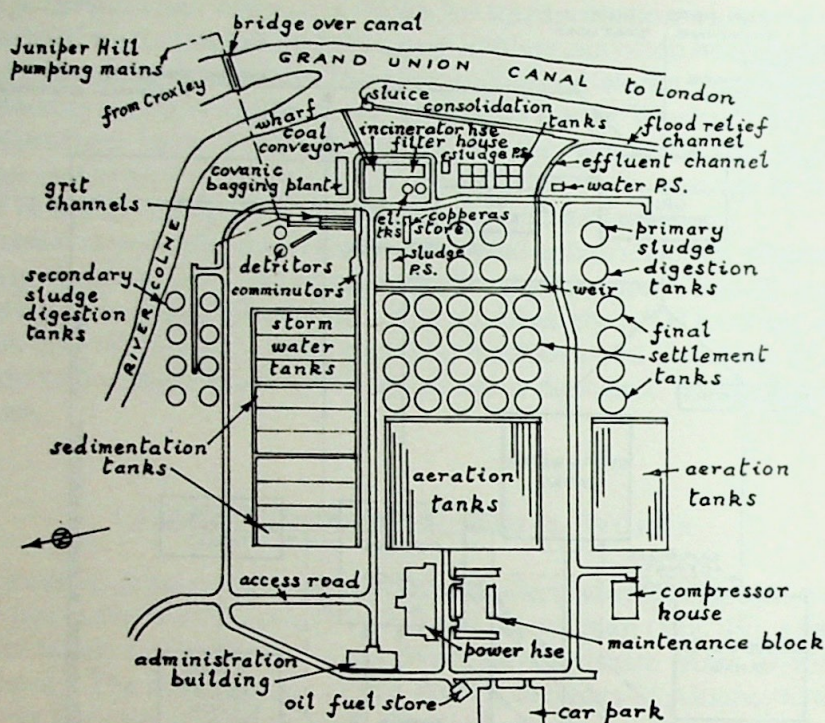


FIG. 49. Maple Lodge Works—Layout plan.

than those of the Code of Practice. A section through a typical small sewage disposal plant, suitable for about 100 persons, is illustrated in Fig. 50.

Small sewage treatment works should be sited a minimum distance of 50 to 300 ft from the nearest dwelling depending on the size of the plant.

The Ministry of Public Building and Works considers that tanks in

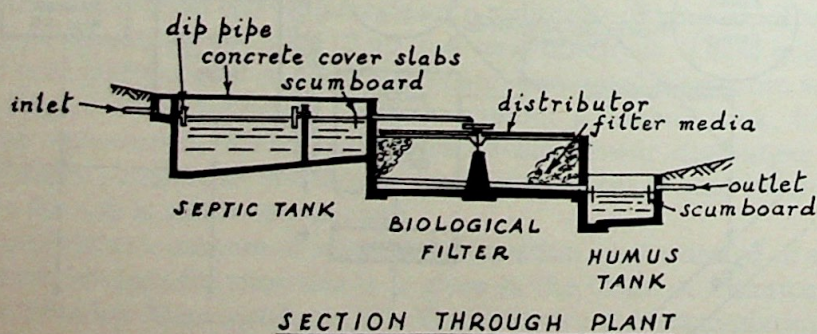


FIG. 50. Small sewage disposal plant.

series give the best effluent, as fermenting solids are trapped in the second tank (13). Recommended tank capacities vary considerably from $30 \times$ the number of persons + 400 gal in the Code of Practice to the following capacities in the Ministry Memorandum:

Sludge capacity of 15 gal/head plus settlement capacity as follows:

Tanks serving up to 10 persons : 48 hr D.W.F.					
„	„	11 to 20	„	: 36 hr	„
„	„	21 to 40	„	: 24 hr	„
„	„	41 to 80	„	: 18 hr	„
„	„	81 to 99	„	: 15 hr	„
„	„	100 or more	„	: 12 hr	„

with a minimum total capacity of 300 gallons.

Septic tanks are usually rectangular in shape, about 6 ft deep with a length approximately 3 times the width. Where there are two chambers, the first should have about $\frac{2}{3}$ of the total capacity. Inlets should consist of dip-pipes and outlets should be dip-pipes for smaller tanks and scumboards and weirs for larger tanks. The tanks are best constructed of 9 in. walls in class 'A' engineering bricks or 1:2:4 concrete and should be covered and ventilated.

Biological or percolating filters should have a capacity not exceeding 45 gal per yd^3 of media per day. The Ministry of Public Building and Works has found that there is no significant operational advantage in the use of clinker, slag, granite or limestone, the choice being governed solely by its physical durability (13). The smaller filters are fed through metal or precast concrete channels with notched sides fed by a tipping trough, but the larger filters need rotating self-dosing distributors.

The filter media should be 3 in. to 4 in. in size for the bottom 6 in. in depth, and 1 in. to 2 in. in size for the remainder. Filters should be at least 4 ft deep and preferably 6 ft. Concrete floors should be laid to falls to drain the effluent to a discharge outlet and the media should be aerated by field drains or special tiles on the concrete floors.

Humus tanks are not recommended for works serving less than 100 persons. They should have weir inlets and outlets protected by a baffle and scumboard in each case. The capacity of a humus tank should be $\frac{1}{4}$ of the septic tank for populations of 100 to 200 and $\frac{1}{3}$ for 200 to 300 persons.

Surface irrigation of filter effluent should be carried out over grass-land or land which has been ploughed in the direction of the contours. The area of land required varies between 1 and 4 yd^2 per head depending upon the nature of the soil.

A rather unsatisfactory alternative to small sewage plants is the provision of cesspools for storage of sewage only. They must be completely watertight to comply with building regulations and will probably need emptying once a fortnight.

Sewage disposal works often incorporate a number of penstocks and valves to control the flow of sewage through the works. Penstocks are made in a variety of types—handstops, hand lifting penstocks, self-sustaining hand penstocks, motor-operated penstocks, screw-operated and self-sustaining weir penstocks, screw-operated balanced penstocks and rack and worm penstocks, each with their own particular uses and advantages. Valves in common use include sluice valves, flap valves, non-return valves, decanting valves, sludge plugs, sludge valves and floating arms.

OPERATION AND MAINTENANCE OF SEWAGE WORKS

Proper maintenance of sewage disposal works is necessary for 3 main reasons:

- (1) To prevent dangers to public health.
- (2) To eliminate foul smells or objectionable sights.
- (3) To prevent the pollution of watercourses.

Much valuable information on the operation and maintenance of small sewage works can be obtained from the Ministry booklet on this subject (14). The actual organisation of the works will vary with its size and location. Large city works will need specialist staffs of chemists, mechanical engineers, etc. operating under a sewage works manager, whereas in rural districts the problem differs greatly with numerous small works scattered over a large rural area.

In rural areas it is generally considered advisable to employ a full-time attendant for works serving about 800 to 2,000 persons, and over this range additional labour will be needed. For smaller works it will be necessary to use a single attendant for two or three works, provided they are not spaced too widely apart. Alternatively, a mobile maintenance gang of 2 or 3 men operating from a van can be used for this purpose, as well as for sewer maintenance.

The main advantages of using full-time attendants as opposed to mobile gangs are as follows:

- (1) The local man responsible for a single works is more likely to take a pride in his works and to obtain a consistently better effluent.

- (2) The full-time attendant is fully familiar with the vagaries of his own particular plant.
- (3) A minimum of time is lost in travelling.
- (4) Mechanical breakdowns or blockages are detected at the earliest possible moment.

The major items requiring constant attention on the smaller sewage disposal works are now listed:

Screening

Screens must be cleared once a day as quantities of accumulated debris can block the screen and cause sewage to back up the sewer. Particular attention must be paid during and after storms, especially if they follow a period of dry weather. Periodically, grit must be emptied from the detritus chambers and valves, penstocks and handstops must be attended to.

Sedimentation Tanks

With horizontal flow tanks it is necessary to draw off the supernatant liquor through a floating arm or fixed decanting pipe prior to removing the sludge, and it is necessary to slow down the rate or removal of liquor when approaching the sludge level. The top water is returned to the works inlet, while the sludge is removed through the sludge valve. The walls, floor, scumboards and weirs of each tank must be thoroughly cleansed on emptying. Desludging of this type of tank should be carried out weekly, otherwise pieces of black rising sludge and gas bubbles will appear on the surface and this may cause ponding of the filters. With upward flow tanks, desludging should be undertaken at least twice a week or the draw-off pipe may become choked with thick sludge.

Septic Tanks

In septic tanks the sludge ferments or digests, reduces in quantity and a crust forms on the surface. When the tank is about $\frac{1}{3}$ to $\frac{1}{2}$ full of sludge the tank should be desludged with a cesspool emptier. About $\frac{2}{3}$ of the sludge is removed and the remainder left to 'seed' the fresh sludge.

Percolating Filters

During cold wintry conditions the 'scouring' organisms penetrate into the filter and some choking of the surface may result. When warmer weather arrives they return to attack the surface layers, resulting in large

discharges of humus during the 'spring offloading' of the filter. Gentle forking of the choked areas from planks and a light sprinkling with bleaching powder will help to remedy the situation.

The filter media should also be kept clear of weeds and moss and all ventilation pipes and channels kept free from obstructions. The sparge holes in the distributor arms must be kept clear and the arms themselves regularly brushed out and flushed. The bearings of the central column require regular inspection and lubrication and the seal and catch chambers need an annual clean. The distributor arms must be maintained in a level position by adjustment of the guy ropes as necessary.

The dosing chambers to filters should be cleaned once a week and the syphons and air pipes given a monthly check.

Sludge Removal

The drying of sludge can be accelerated by forming holes or narrow paths in the sludge on drying beds once it has started cracking. Another useful method is to insert vertical porous land drain pipes at intervals over the bed. As sludge dries much more slowly in winter, it is desirable to have as many empty drying beds as possible available for use at the start of the winter. From time to time the top layer of ashes needs to be made up to the normal finished level, as some ashes are removed with the dried sludge on each occasion.

Mechanical Equipment

All mechanical equipment requires constant checking, oiling and greasing and the manufacturer's instructions for the care and maintenance of motors, pumps and electric switch gear should be consulted and closely followed. In particular, glands should be checked frequently, pump shafts occasionally turned by hand to see that they rotate freely and floats and electrodes frequently inspected, cleaned and lubricated.

General Matters

Some protection of parts of the works, such as screen bars and dosing syphons, by tarpaulins or windbreaks may be desirable in severe frosts. It may also be advisable to shut down some of the filters under these conditions.

All works should be maintained in a clean and tidy condition as far as available labour permits.

Samples of effluent should be taken periodically for analysis and labelled 'crude', 'settled' or 'final'. In addition the field test for perman-

ganate value devised by the Water Pollution Research Laboratory should be carried out at least once a week.

An alteration in the colour or general appearance of the crude sewage may result from a discharge of factory or farm waste into the sewers and deserves investigation. An increase in the quantity of suspended matter in the effluent from sedimentation or humus tanks probably indicates that these tanks require more frequent desludging. If the final effluent is dull and cloudy, there may be a defect in the working of the filters.

It is most important that full safety precautions should be observed in sewage disposal works, particularly when entering confined sumps or manholes. Safety equipment should be inspected regularly and a workmen's accident record book be made readily available. Further information on this aspect is given in a publication of the Institution of Civil Engineers (15).

Readers requiring further information on the disposal of sewage generally are referred to the book by T. H. P. Veal (16).

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CHAPTER SEVEN

Public Cleansing

THE term 'Public Cleansing' embraces the collection and disposal of house and trade refuse and the cleansing of streets maintainable by local authorities. It is an essential yet costly service which must be operated if reasonable standards of hygiene are to be maintained.

COMPOSITION AND YIELD OF HOUSE REFUSE

Widely varying figures are available giving the typical composition of house refuse and they serve to illustrate the considerable variations in the content of constituent materials which arise in practice. The following schedule (Table 7) gives a breakdown of the main constituents of typical house refuse pre-war and in 1962, broadly based on investigations carried out by the Institute of Public Cleansing and published in a paper presented by J. Sumner (see reference 1 at the end of this chapter), while the estimated 1964 figures are extracted from a paper presented by L. P. Brunt (2).

Table 7 shows that the composition of house refuse has changed considerably in the past 25 years. In particular the fine dust and cinder content of the refuse has dropped appreciably, as is to be expected with the greater use of central heating and smokeless fuels. Vegetable and putrescible matter is reducing in quantity while paper and cardboard, metals and glass are all on the increase due to the changing pattern of food purchases. Hence the proportion of offensive matter is reducing whilst that of salvageable materials is increasing.

The following set of figures indicates the changes in the volume and weight of refuse collected per house (1).

	<i>National pre-war</i>	<i>Average 1962</i>
Density of refuse (lb/ft ³)	18.15	15.36
Average weight of refuse per house per week (lb)	37.54	31.05
Volume of refuse per house per week (ft ³)	2.07	2.08

These figures show that house refuse is now lighter in weight for a given volume, but that the volume collected per house is much the same as pre-war, even although the average number of occupants per house has fallen. The weight of refuse collected per 1,000 population has in fact increased, due to the lower occupancy rate (15 to 16.2 cwt).

TABLE 7. ANALYSES OF HOUSE REFUSE

<i>Constituent materials</i>	<i>National pre-war %</i>	<i>Average 1962 %</i>	<i>Estimated average 1964 %</i>
Fine dust and small cinder (under $\frac{1}{2}$ in.)	36.5	30.5	30.0
Cinder ($\frac{1}{2}$ in. to $1\frac{1}{4}$ in.)	20.5	13.0	12.0
Vegetable and putrescible matter	13.0	11.0	10.5
Paper and cardboard	14.5	21.5	25.0
Metals (ferrous and non-ferrous)	4.0	6.5	7.5
Rags (textiles)	2.0	2.5	2.5
Glass	3.5	8.0	8.0
Unclassified debris	6.0	7.0	4.5
	100.0	100.0	100.0

STORAGE OF REFUSE

The most common method of storing house refuse prior to collection is still by the use of steel dustbins. Local authorities mainly advocate the use of British Standard tapered pattern bins, to B.S. 792, made of galvanised steel with capacities of 2, $2\frac{1}{2}$ and $3\frac{1}{4}$ ft³ and with weights ranging from 20 to 28 lb. Much cheaper non-standard galvanised corrugated steel dustbins are very popular with private landlords. The most common sizes are 24 in. $\times$ 18 in. diameter and 20 in. $\times$ 16 in. diameter, with weights ranging from 14 to 20 lb. The average life of the non-standard dustbins is less but it may still prove to be the most economical long-term proposition.

Dustbins are now being manufactured in other materials such as rubber, glass fibre and combinations of rubber, plastics and metal. The

use of metal bins with rubber lids has much to commend it from a reduction of noise aspect. Another fairly recent innovation is the use of paper sacks, where the local authority undertakes the provision of the sacks, and this system will be considered in more detail later in this chapter.

Bulk containers are needed for the storage of refuse from large blocks of flats and commercial properties. The construction of these containers is covered by B.S. 1136, their nominal capacity is $1\frac{1}{4}$ yd³ and they are used in conjunction with vehicles fitted with special lifting attachments.

Most blocks of flats are provided with built-in refuse chutes of glazed vitrified clayware pipes with a minimum diameter of 15 to 18 in., which discharge into bulk storage containers, housed in enclosed chambers at ground level. The Code of Practice (CP 306) gives much valuable guidance on this aspect (3), from which it will be noted that chutes should have access doors at every third floor and be ventilated to free air.

As most flats are centrally heated, a large quantity of bulky refuse is produced which soon fills bulk containers, particularly during the Christmas holiday period. A few authorities have overcome this problem by installing turntables carrying 4 or 6 containers, and each container is placed under the chute in turn and this reduces the number of chutes required and increases the period between the emptying of containers.

Another alternative method is to house the refuse containers in separate buildings away from the flats and equip the tenants with small covered pails which they empty into the containers. This method causes some inconvenience to the tenant but overcomes complaints about blockages, noise and smell from chutes.

Yet another method, which has not been used very extensively in this country, is the 'Garchey system'. In this system the kitchen sink is fitted with a 6 in. outlet and waste unit, which receives solid objects, such as tins and bottles, but leaves larger objects still to be removed by some other method. By turning a waste grid in the sink, a valve is opened which allows the waste material to pass down the waste pipe to a collection chamber, which is normally constructed below ground level in concrete. An overflow from the collection chamber enables any surplus water to pass into the sewerage system.

A purpose-made tanker can be used to pump out the contents of the collection chamber, compressing the solid refuse in the tanker and discharging the liquid into the sewerage system. The system is completely enclosed and ventilated at roof level, thus eliminating any nuisance from insects or flies. It contains no motors, has a minimum of moving parts and requires the normal amount of waste water only for its effective operation (4).

Kitchen or garbage grinders are being installed, particularly in business premises, for the grinding of food wastes and their disposal through the sewerage system, to eliminate much of the nuisance from smell and flies. The sink units usually have $3\frac{1}{2}$ in. outlets and the wastes are fitted with electrically-operated grinders which shred the solid matter and enable it to be carried away by water. Wholesale use of garbage grinders would result in a large increase in the quantity of settleable solids and sludge at sewage disposal works (5).

Another process which is being developed is the daily incineration of the refuse on the premises in an electrically operated incinerator. The ash is discharged into a bin each morning and it is claimed that a 3 ft^3 dustbin will hold the ash and tins produced by a household of 7 persons over a 3-week period. One incinerator could serve a complete block of flats.

DOMESTIC REFUSE COLLECTION

Domestic refuse is normally collected weekly with 2 collections weekly from hotels, canteens and restaurants during the summer period. A few city authorities have introduced bi-weekly collections and some rural councils make only fortnightly collections.

There are five principal methods of collecting refuse, as listed in the Institution of Municipal Engineer's Memorandum to the Ministry of Housing and Local Government (6), and each of these will now be considered:

(1) Bins are brought out and left at the kerbside by householders ready for emptying by the refuse collectors. The main advantage of this method is that it reduces labour costs by about 30 per cent. It is, however, little used in practice as it has many disadvantages, such as the possibility of augmentation of bins with other and unsuitable receptacles, the possibility of lids being blown off or removed by children and of scattering of contents of bins, the unsightly appearance of rows of bins on the public footpath for long periods and the undesirability of aged and infirm residents having to carry heavy bins to the kerbside.

A compromise system is for the refuse collector to carry the bin from the house, empty it and leave it by the kerbside for return by the householder. This method has many of the disadvantages of the previous system, but overcomes the problem of bins being taken to the kerbside by householders and then not being emptied on the scheduled collection day due to a breakdown or some other cause.

(2) Bins are brought by the refuse collectors to the vehicles, emptied and

returned to the houses. This is probably the most usual method and involves high labour costs, but reduces the possible nuisance that can arise from the use of 'skeps' or 'skips', which resemble portable bathtubs.

(3) The refuse collectors empty the refuse from bins into open skeps at the houses and carry the loaded skeps to the vehicle for unloading, thus eliminating the return journey to the house and reducing the time required for collection purposes. This is an unsatisfactory method of collection, as some of the contents of the bins are almost invariably split near the house and more is often blown out of the open skep on the way to the refuse vehicle. Furthermore, the standard skep size of $2\frac{1}{2}$ ft³ is less than a common bin capacity of $3\frac{1}{3}$ ft³, so that skeps are frequently filled to overflowing and complaints from householders of spilt refuse on their property are quite common.

(4) The system envisages the use of special hinged-lidded bins and vehicles with a mechanically operated shutter device fitted to the rear of the collection vehicle, to provide dustless collection. The bins are provided with special attachments which permit them to be fitted to the shutter on the vehicle, and this enables the bin to be emptied with little manual effort and practically no dust emission. The refuse is moved into the body of the vehicle by a compression process.

By 1962, this method of collection had been adopted for about one-third of Birmingham and showed increased labour costs compared with the former skep method of about 30 per cent. Nevertheless, it is a much more hygienic and satisfactory method of collection (1).

This method is also used for much of the St Marylebone borough on a bi-weekly collection. Considerable advance notice was given to traders and householders prior to introduction of the system, to prevent them purchasing new bins which could not be used with this method of collection. Domestic bins are supplied free of charge and those for trade use are supplied free on loan by the local authority. To render the hinged-lid bins less noisy, plastic rings were fitted to the underside of the lids and rubber rings to the bottoms of the bins. Unfortunately, these rings increased the weight of a bin by 4 lb and with $2\frac{1}{2}$ ft³ bins and lighter refuse, gave an unsatisfactory contents/bin weight ratio of 0.73. Consideration will probably have to be given to the use of lighter bins, possibly using new materials such as glass-fibre (7).

(5) The use of paper bags also practically eliminates the possibility of spillage of refuse and again necessitates the local authority supplying the receptacles. The equipment consists of a sack-holder and paper sacks and permits the operation of an efficient, dustless and hygienic collection system. The sacks are usually made from 2-ply wet strength kraft paper,

normally of standard weight with taped and sewn or glued bottom and glued (anti-acid) sides. They are made in a variety of sizes, of which the most commonly used has a nominal capacity of $2\frac{1}{2}$ ft³ and a nominal diameter of 14 to 16 $\frac{1}{2}$ in.

Various sack-holders or head units are available to support the paper sacks, of which the following are the most usual:

- (a) Mounted to walls.
- (b) Mounted to fencing posts.
- (c) Free-standing—usually attached to a metal or concrete stand with a suitable base.

Each type incorporates a head-unit with a lid of metal, plastic or rubber, to close the mouth of the sack. Other types include mobile units on castors for offices and hospitals, sliding units for fixing in cupboards to flats and those guarded with a wire mesh cage to provide protection against animals.

The main advantages of the system are dustless and hygienic operation if the container is replaced every week, and a reduction in labour requirements to slightly less than those of the skip system. Furthermore, it provides cleaner and better working conditions for the men with considerable reduction in the weight to be carried ($\frac{1}{2}$ lb paper sacks as compared with metal bins weighing over 20 lb each). It permits of greater flexibility in the choice of refuse collection vehicles and leads to improved conditions on refuse tips.

Paper sacks will successfully withstand adverse weather conditions and hot ashes for reasonable periods between collections. They do not accommodate as much refuse as a metal bin, involve the local authority in large stocks of sacks, and need breaking to allow sorting of contents.

They do, however, represent considerable progress in refuse collection methods and are of great value where refuse has to be carried through premises or where additional refuse may accumulate at holiday periods. It is also most desirable that the local authority should provide the storage receptacle and so eliminate the troubles that arise on occasions due to owner/occupier responsibility.

The daily allocation of bins to refuse collecting teams usually operates in one of two ways:

- (1) The continuous system, in which the bins are emptied in strict rotation and collection work terminates towards the end of the working day, regardless of the point reached by the collectors.
- (2) The task system, in which there is a pre-determined number of bins to be emptied each day, and the refuse collectors finish work when the

pre-arranged number of bins have been emptied. This method is essential when the householder is responsible for placing the bin at the kerb-side.

The number of men in a refuse collection team or gang varies considerably in practice, and is influenced by the spacing of bins, method of collection, type and capacity of vehicle and length of haul to point of disposal. For instance, the optimum size of an urban refuse collection team is often 5 to 6 men, whereas the corresponding figure with a rural team would probably be 3, on account of the large amount of unproductive time spent travelling from village to village.

The number of bins emptied per man per day varies tremendously according to working conditions and even the time of the year. An average would probably be about 130 bins per man per day.

TRADE REFUSE COLLECTION

Trade refuse may be collected weekly, bi-weekly or even daily in the case of putrescible wastes. The wastes from fishmongers' premises can be particularly offensive and require frequent removal. Local authorities are empowered under the Public Health Act, 1936 (section 73) to make reasonable charges for this service. It is common practice to allow one free bin per week from each property and to charge additional bins at about 1/- per emptying or possibly an annual charge of about 40/- for each additional bin.

Disputes have arisen from time to time as to what constitutes trade refuse. As a result of case law it has been established that steam boiler ash is trade refuse together with all waste products arising from manufacturing processes, whilst hotel and tea-shop refuse is classed as house refuse.

It is customary to collect trade refuse in bulk containers, which are made in varying types and sizes to suit the particular collection requirements. The main requirements are speedy and relatively easy transfer of container to collection vehicle and the discharge of the contents into the vehicle without causing a nuisance. A further step in this process is the mechanical cleansing of the containers by the local authority, and a scheme of municipal bulk container hire has much to commend it.

Some local authorities, notably West Bromwich, are undertaking an industrial waste collection service from factories. They take the view that it is wholly unsatisfactory to allow industrialists to dispose of trade waste by burning it on open ground or by the use of unsuitable

methods of incineration, and that a municipal waste collection service will prevent this. Large-capacity containers, often of about 8 yd³ capacity, are hydraulically lifted on to motive units and discharged at the tip, without the driver having to leave his cab.

The Institution of Municipal Engineers' Memorandum drew attention to the increasing practice of dumping of bulky items by private persons on open land, ditches, grass verges, etc. The materials dumped range from household furniture, hedge and grass cuttings, building debris, scrap materials and even unwanted vehicles, and they can create a terrible eyesore. Most local authorities will collect household furniture free of charge but garden waste should be composted. Building debris and scrap materials usually constitute trade refuse, whilst special plant will be needed to dispose of unwanted vehicles, probably shared by a number of local authorities (6).

WELFARE PROVISIONS

With the ever-increasing labour shortage it behoves all local authorities to provide ample welfare facilities for refuse collectors, who undertake a very dirty, arduous and unpleasant job. Essential depot facilities include lockers for the storage of the operatives' own clothing while they are at work, an abundant supply of hot water and showers for washing, clothes drying equipment and sufficient toilets and mess accommodation. It is possible to attach hot water storage containers to refuse collection vehicles, which can be filled with hot water before each vehicle leaves the depot in the morning.

Another important item is the provision of adequate protective clothing for men engaged on public cleansing work. The main functions of protective clothing are to protect operatives from injury, to relieve the operative of the need to supply clothing which can be subjected to excessive wear or damage due to the type of work he undertakes, and to provide protection from the weather. The provision of protective clothing also helps to attract workers, encourages greater output and assists public relations.

It is advisable to purchase the clothing in bulk to secure the most advantageous prices and to store it in cool, well ventilated stores. Two sets should be supplied to each operative and provision made for regular laundering, where applicable, to give maximum length of service. Refuse collectors are normally supplied with a P.V.C. raincoat or leather jerkin, leggings, gloves and aprons; all of which are now covered by British Standard Specifications.

INCENTIVE BONUS SCHEMES

There is little doubt that maximum output on refuse collection work, in common with many other municipal services, cannot be achieved without introducing incentive bonus schemes. In addition to raising output, an incentive bonus scheme produces happier workers as they receive higher wages and the cost to the local authority of operating the service is reduced.

Fortunately, this is one of the easiest services to which to apply incentive bonus schemes. Some work study is an essential preliminary to determine a reasonable number of bins that can be emptied in each collection district, to provide target performance values or standards, and bonus is then payable on the number of bins emptied over and above the standard figures. It is generally found that the average worker can achieve a performance level about 30 per cent above normal working without detrimentally affecting his health. The savings in cost due to increased output are normally shared between the operatives and the local authority, and drivers of refuse vehicles receive the same share of bonus as the refuse collectors (8).

REFUSE COLLECTION VEHICLES

Basically, refuse collection vehicles, of which there are a large variety of different types, can be classified in two ways:

- (1) The method of loading—side, rear or top.
- (2) The method of operation—moving floor, spiral screw, rotating drum, pressure packing plates, continuous loading, gravity and dustless loading.

The actual type and size of vehicle used will be largely determined by the characteristics of the area in which it is to operate. Similarly, a decision as to whether to use petrol or diesel engined vehicles will be largely influenced by the distance to be travelled, to find if the higher initial cost of the diesel engined vehicle will be offset by savings in fuel costs.

Side Loaders

The simplest form of refuse vehicle is the side loader with its low initial cost and relative ease of maintenance. Side loaders permit direct loading from the kerbside, which is more convenient for the men but

less satisfactory for the public, and the use of trailers for storage of salvage or other purposes.

End Loaders

The majority of vehicles used today are of the rear or end loading variety, which is more satisfactory from the public viewpoint and makes for easier working in narrow back streets. The main types of end loading vehicle will now be considered:

Barrier Loaders. Refuse bins have to be carried up steps into the vehicle and emptied over a barrier which compresses the refuse on the other side. This type of vehicle is not widely used and produces unpleasant working conditions in the vehicle.

Gravity Loaders. These are mainly of the fore and aft variety and are extremely popular. The body of the vehicle rotates vertically through 90° causing partial compression of the refuse due to gravity.

Moving Floor Loaders. Some compression of the refuse is obtained by the floor of the vehicle moving forward by hand or power operation. This is not a very popular type of vehicle.

Spiral Screw Loaders. A worm mounted in the upper section of the vehicle rotates as the collection of refuse is proceeding. The refuse is carried forward and considerable compression takes place.

Rotating Drum Loaders. A rotating drum carries the refuse along a fixed internal spiral assembly.

Loaders with Pressure Packing Plates. The refuse is discharged over a rail at the rear of the vehicle and at intervals a power-operated packer plate passes along the rear portion of the vehicle. This compresses the refuse and provides further loading space.

Continuous Loaders. Refuse passes through a hopper on to an inverted drawer, which reciprocates slowly while loading is taking place. As the drawer retracts the refuse on it drops and is then pushed forward into the vehicle on the next stroke. There are variations of this process, some introducing a 'chopping action' on large items of refuse and sacks.

The Institution of Municipal Engineers favoured the use of continuous

loaders in conjunction with large, specially manufactured skeps, for economical working and a minimum of nuisance (6).

Dustless Loaders. The discharge of the bin is performed within the refuse vehicle, using one of the sealing-flap devices and specially designed bins. This system is the most expensive but is the most satisfactory from the hygiene aspect. Trolleys are desirable to transport the heavier bins to the vehicle and the local authority must provide the bins. A municipal bin system does however ensure uniform type bins in good condition throughout the collection area, thus reducing collecting time, and permits the bulk purchase of bins at lower prices.

Refuse Collection Vehicles Generally

Side loaders have a range of capacities from 3 to 16 yd³, fore and aft tipplers from 12 to 25 yd³ and continuous loaders from 8 to 50 yd³. The overall dimensions of refuse vehicles range from 16 ft × 7 ft to 26 ft 6 in. × 8 ft. All modern refuse collecting vehicles are of sturdy construction, usually of non-corrosive light alloy for the main structure, with spacious comfortable cabs, low loading heights and cab-operated controls. Compression ratios on power-compression collection vehicles range from 1.5 to 3.0:1, depending on the density of the refuse.

Refuse collection vehicles are subjected to very heavy wear and tear and thus require thorough and regular maintenance. It is insufficient to rely on a driver spending an hour to two a week greasing and maintaining his vehicle. Skilled maintenance staff are needed to carefully and regularly clean and lubricate all moving parts and to inspect and adjust all gear. Efficient inspection techniques and suitable workshop accommodation are essential for all but the smallest authorities as emphasised in the paper by P. K. Patrick (9).

REFUSE DISPOSAL

Various methods of refuse disposal are operated in this country, of which the principal methods are:

- Controlled tipping.
- Incineration.
- Pulverisation.
- Composting.

Each of these methods will now be considered in some detail.

Controlled Tipping

Controlled tipping is the most widely adopted method of refuse disposal in this country, and usually the most economical. The process is essentially one of biological fermentation due to thermogenic organisms which are present in the organic matter. The biological action results in the temperature in the tip rising to between 150 and 160°F within a few days. Temperatures in this range will destroy pathogenic organisms, with the exception of anthrax.

The Ministry of Health has issued Model Byelaws covering the operation of refuse tips with a view to reducing the amount of nuisance. The refuse should be tipped in layers with a maximum depth of 6 ft and in the form of 'fingers' about 20 ft wide to isolate tip fires. All exposed faces of the refuse should be covered with 6 in. to 9 in. of soil, preferably within 24 hours of being deposited. Fish and animal wastes should have a minimum coverage of 2 ft.

The deposited refuse settles to the extent of about 10 to 15 per cent and decomposes to an earthy material after about 4 years, whilst a complete breakdown occurs after 7 to 10 years with decomposition of ferrous metals and paper. It is essential to enforce strict rodent control on tips and to spray freshly tipped refuse with insecticides, mainly based on aromatic oils or kerosene, to kill flies and mask odours.

It is well-nigh essential to use mechanical earth-moving equipment on refuse tips to consolidate the refuse and keep it covered, although some of the less enlightened local authorities do not consider it necessary. With smaller authorities there may well be a case for joint ownership of mechanical equipment.

Crawler tractors with large blades are particularly suitable for use on refuse tips as they can operate satisfactorily in loose material, cannot suffer breakdowns through punctures, provide even consolidation over quite a wide area and can crush bulky metal objects. Wheeled vehicles, on the other hand, can be operated at a lower cost and can travel more easily from site to site, but they are not so satisfactory or as manoeuvrable on the tip.

It is becoming increasingly difficult in some areas of the country to find suitable tip sites, although in other districts they have assisted in the provision of playing fields and parks or in the reclamation of land for agriculture. In some cases it has been necessary for local authorities to take joint action on a regional basis and to set up transfer loading stations, for the transfer of refuse from collection vehicles to bulk transporters, where exceedingly long hauls are involved (11).

The simplest form of transfer loading station consists of elevated

slotted reinforced concrete decking, through which refuse is forced by bulldozers into bulk transporters located below. Purpose-built mechanised stations are operating at Salford and St Pancras, with reception hoppers, elevators and conveyors, providing for separation of refuse and mechanical loading of bulk transporters. Bulk transporters are usually of about 35 to 40 yd³ capacity with moving slatted floors or a compression ram.

On occasions it is necessary to tip refuse on sites with fissured formations which could cause contamination of ground water. To ensure satisfactory operation, it is necessary to waterproof the base of the site and drain away the percolating liquid, usually by means of land drains discharging into the foul sewerage system.

Experimental work has also proceeded at Egham, with the tipping of refuse into waterlogged gravel pits. The pits were divided into lagoons of about 2 to 3 acres in area by earth banks, with tipping proceeding as quickly as possible. A portable boom was located about 30 ft from the tipping face to confine floating matter, and the water was subjected to compressed air and treated with chlorine, as necessary, to maintain aerobic conditions and prevent aerial nuisance. Full consideration must also be given to the possibility of contamination of ground water having regard to location of sources of water supply and their rate of abstraction, the direction of flow of ground water, the tipping rate and type of subsoil around the tip (10).

Incineration

Incineration of town refuse is carried out by some of the larger local authorities, mainly because it is desirable to keep the quantity of tipped refuse to a minimum, due to limited space available and long hauls. With incineration plant, it is usual to separate materials which can serve a useful purpose, and the plant often provides for initial storage, continuous flow, salvage recovery for subsequent baling (hand or power-operated) and screening of fine dust. Modern plants frequently use rotary screens for removal of fine dust, magnetic separation of ferrous metal, and fully mechanical continuous grates. It is essential that flue gases are properly cleansed and efficient grit extraction plant installed. The most common systems are water sprays in conjunction with a water trough or electro-static precipitators (12).

Waste paper recovery has saved about £500 million of wood pulp imports over a 10-year period. Nevertheless, many local authorities frequently experience difficulty in disposing of waste paper at a reasonable price.

Pulverisation

The treatment of refuse by pulverisation prior to disposal has become more popular, largely because it reduces the amount of tipping space required and lessens the nuisance from flies and vermin. The pulverised or crushed material can often be tipped on sites which would not otherwise be available for the deposit of refuse, as it is relatively innocuous and can be readily consolidated. Furthermore, the plant is of lower capital cost than incineration or composting plant. After a period of 1 or 2 years this material could be used for covering untreated tipped house refuse.

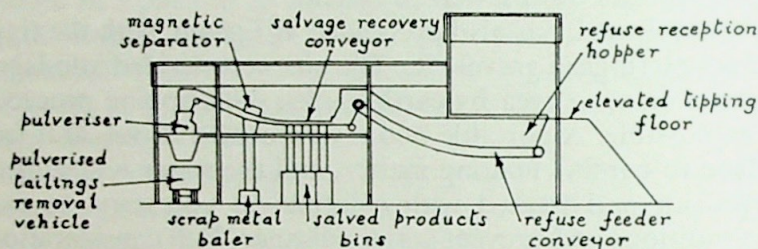


FIG. 51. Refuse pulverisation plant.

There are a number of pulverisers available of which the swing hammer type is often used, in which the hammers are rotated close to a static casing and grid screen. Another type consists of a horizontal rotating drum in which a set of knives is fixed to a central shaft rotating in the opposite direction (1). A typical refuse pulverisation plant is illustrated in Fig. 51.

Composting

Considerable interest has been aroused in recent years by the possibilities of composting as a means of treatment of refuse, possibly in conjunction with sewage sludge, for disposal as a soil conditioner. Unfortunately, it has been found in practice that not more than about 50 per cent of the refuse is suitable for composting and it is not always possible to sell the compost at a reasonable price. The compost is in the nature of a humus or soil conditioner rather than a fertilizer, and its main use at present appears to be for horticulture or on private gardens, rather than in agriculture.

The Government publication on this subject in 1954 (13) gave a rather gloomy picture, but many local authorities are now considering this method mainly because of shortage of tipping space. The principal

advantages of composting would seem to be that the refuse is rendered harmless and treated in such a way that it can supply humus to the soil and so improve its quality. The nutrient value of the compost can be further increased by the addition of sewage sludge, whose disposal is often very difficult.

Leicester corporation is converting all its sewage sludge, mixed with 330 tons of domestic refuse daily, into an agricultural compost and this is the largest scheme of its kind in Europe. It took 4 years of experimenting to produce the desired formula for the mixing of the two wastes. It was necessary to set up a distribution agency for delivery of the compost, and it was felt that it provided farmers with an opportunity of maintaining their land in good heart at reasonable cost, particularly as so many artificial fertilisers did little to recondition the soil (15).

A variety of different types of mechanical composting plants have been developed in recent years. They vary from retention in slowly rotating horizontal steel drums into which air and moisture (sewage sludge, gas works liquor or water) are added under controlled conditions to vertical towers containing a number of collapsible floors which permit the refuse to fall in stages against an upward air stream. Another system provides for retention in expanded metal cages or static steel or concrete digestors, to which air and moisture are injected, and provision is made for mechanical agitation of the refuse. The normal retention period is about 5 to 7 days, after which the compost is removed to mature, usually in the open.

All types of plant incorporate handling equipment for the reception, storage and feeding of the refuse to composting units and for pulverising the material to remove particles of glass and other undesirable materials (1). Readers requiring further information on composting are referred to the book by P. Wix (14).

It is interesting to note that the South African Government authorities have recommended the use of mechanical composting, to overcome municipal waste disposal problems and to increase the supply of organic material for use on cultivated soils, which have been subject to much soil erosion (16). Refuse-processing requirements vary in different countries due to the variations in the quantities of the constituent items in the refuse.

STREET CLEANSING

Street Washing

The most effective and hygienic method of street cleansing is by washing or flushing. This method is little used today largely on account

of the shortage of water in the summer months and the considerable quantities of water needed. For instance, about 400 gallons of water are required to flush a mile of channel.

Most gully emptiers and mechanical sweepers are fitted with sprinkler heads and fish-tail jets and can thus be used for street washing. One vehicle can wash about 20 miles of street in a day.

Mechanical Sweeping

Streets can be swept by machine or hand, but about 60 per cent of street sweeping is now carried out mechanically for increased efficiency and to overcome the acute labour shortage. There are various types of mechanical road sweeper available, some with a brush of approximately the width of the vehicle set at an angle, to brush the sweepings into the channel, while others sweep the channel only and some do both. Most varieties pick up the sweepings with elevating gear or suction lift, hold them in a suitable container and carry water for spraying purposes. The brushes need to be tough, resilient and highly resistant to water, oil, grease and salt—bristle and bass are now being replaced to some extent by more durable manufactured materials such as polypropylene and high tensile steel.

Mechanical sweeping is adversely affected by heavy traffic and parked vehicles and this is sometimes overcome by adjusting the time of sweeping to avoid heavy traffic (night or early morning sweeping) and the introduction of unilateral parking. The suction type of sweeper can cope more successfully with severe conditions, such as heavy falls of leaves, and they are usually fitted with a wandering hose which can be used for gully emptying, lifting piles of heavy grit, footpath cleaning and emptying litter and orderly bins.

Mechanical sweepers can effectively sweep about 100 miles per week and pick up about 10 to 12 tons of sweepings in this period. Performance is however affected considerably by the quantity and type of sweepings, the type of road surface, topography of the district, traffic conditions, etc. The refuse capacities of mechanical road sweepers vary from 2 to 8 yd³.

Hand Sweeping

Hand sweeping is particularly well suited for the cleansing of footpaths, where litter is still dropped continuously despite the passing of the Litter Act and a generous distribution of litter bins. The daily length of an individual beat is usually in the order of 1 to 1½ miles, although it varies considerably with the frequency of sweeping, traffic conditions

and ancillary duties of the operator. Central areas of towns need sweeping at least once daily and residential areas, once or twice weekly. This method of sweeping has the advantage of adaptability but it is becoming increasingly difficult to recruit the necessary labour.

This system envisages the use of orderly trucks, which usually consist of a metal-frame chassis supported on two pneumatic-tyred wheels with one or two lidded bins with a total capacity of 2 to $4\frac{1}{2}$ ft³. The bins can be of various materials, such as light sheet metal, plastics, glass-fibre or paper sacks. The contents are normally discharged into orderly bins of about 1 yd³ capacity, for periodic emptying by refuse collectors. Gangs of sweepers may be supplied with pedestrian-controlled motorised orderly trucks.

The majority of brooms have ash shafts and beech stocks with Bahia or bass tufting. The average life of the tufting or bristles is about $2\frac{1}{2}$ to 3 weeks.

Gully Cleansing

The emptying of road gullies is normally performed about 4 times a year, using mainly diesel-engined gully emptiers with a capacity of about 800 to 1,000 gallons. On average, they deal with about 100 gullies per day, removing about $1\frac{1}{2}$ tons of sludge and filling each gully with approximately 10 to 12 gallons of sealing water.

The suction lift is usually obtained from a rotary pump which creates a partial vacuum. Discharge of sludge can be made by hydraulic tipping gear, piston compression, worm gear or a pump.

Weed Control

It is most desirable that all weeds on public paved surfaces should be effectively destroyed with suitable herbicides or weed-killers. The herbicides are of two main classes—selective and non-selective and of three types—contact (killing at place of contact), translocated (absorbed by plant) and residual (retained in soil and attacking plant through roots). In practice it is good policy to use a combination of translocated, residual and selective herbicides.

Weed-killers can be obtained in powder, granular or liquid form, of which the liquid variety is best suited for application by mechanical equipment. They should be applied during March to June to give the best results. The best distribution equipment is probably a portable petrol or diesel-engined pump and free-standing tank carried by a trailer or vehicle. Spraying is undertaken with hand lances or tractor-mounted multi-head booms (17).

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CHAPTER EIGHT

Water Supply

THIS chapter is concerned with the supply, storage, purification and distribution of water. It is appreciated that the water supply functions of many local authorities have been transferred to separate Water Boards, but the author felt as it was a subject of such vital importance and with such far-reaching effects on local government activities that it ought not to be omitted from this book.

WATER CONSUMPTION

Water consumption can be subdivided into three main classifications.

- (1) Domestic.
- (2) Industrial and trade.
- (3) Agricultural.

(1) Domestic Consumption

Domestic consumption is increasing at a considerable rate as the standard of living is improved. Almost 100 per cent of urban dwellings now have a piped water supply and probably about 95 per cent of rural dwellings. Improved housing conditions, more attention to personal hygiene and the extensive use of garden hoses have all tended to increase the rate of domestic consumption.

The present national average domestic consumption of 25 to 35 ghd (gallons per head per day), could well rise to 40 to 50 ghd by 1980. When estimating future water needs, it is essential to endeavour to calculate the probable increased consumption per head in addition to the projected increase in population.

(2) Industrial Consumption

There are wide variations in industrial water consumption throughout the country and on average it probably amounts to about 10 ghd. In the past the industrialist often provided his own source of supply but since the passing of the Water Act, 1945, water undertakings are required to provide supplies for other than domestic purposes.

Certain industrial concerns are very heavy water consumers, and some expanding towns have attracted industries whose high water consumption has put a heavy strain on the towns' immediate resources. In North East Lincolnshire the total consumption has reached 120 gpd (gallons per day) due to a concentration of chemical and food processing plants (see reference 1 at the end of this chapter).

(3) Agricultural Consumption

The water consumption of cattle is about 30 gpd for each cow in milk and 10 gpd for other cattle. Market gardens often require substantial water supplies and large glasshouses may need an average of about 2,500 gpd per acre (2).

SOURCES OF SUPPLY

A variety of sources of supply are used, principally springs and rivers, wells and boreholes, and catchment areas feeding impounding reservoirs. In the past the north and west of the country obtained their supplies mainly from impounding reservoirs, and the south and east mainly from boreholes. A limited number of authorities obtained their water directly from rivers and this source of supply is likely to assume greater importance as ground water sources become insufficient to meet growing demands. This in its turn will call for higher standards of purity in rivers and for positive action by River Authorities, under the Water Resources Act, 1963, to undertake conservation of water resources. It should perhaps be mentioned that conversion of sea-water is not an economical proposition and a water grid is hardly practicable.

Rainfall is recorded daily by rainfall gauges located throughout the country by a variety of persons and organisations. The average annual rainfall in this country ranges from about 20 in. in south-east England to over 80 in. in the north-west of the country. The quantity of water which runs off the surface or percolates through to underground sources is much less than the actual rainfall, due to losses through evaporation, absorption and percolation.

Impounding Reservoirs

Impounding reservoirs consist of dams constructed across river valleys or embankments around flat areas, to hold excess flows in store for use during times of low river flow. Extensive records of river flow gaugings need to be carefully examined to determine the potential yield of the source, with particular reference to the three driest consecutive years (1933–6 is usually taken for this purpose). Detailed information on the estimation of the yield of impounding reservoirs is given in the book by A. C. Twort (2).

Dams forming impounding reservoirs are very expensive structures, often costing between 1 and 2 million pounds. They must be sufficiently strong, durable and watertight, with provision for drawing-off water for supply purposes, as required, and to permit flood waters to safely by-pass the dam. Geological surveys and borings precede the design of the project.

Many dams are constructed of consolidated earth with a central core of puddled clay or rolled clay fill, extending below ground level to an impermeable strata with a *cut-off trench* filled with concrete. The upstream face of the dam is often finished with precast concrete slabs laid on gravel at a slope of about 3 to 1. Other forms of construction include masonry, mass concrete, reinforced concrete and prestressed concrete.

In all cases overflows have to be incorporated to deal with flood waters. With masonry and concrete dams direct weir discharges can be made over the dam and with all types of dam the flood water can be diverted by a spillway channel around the end of the dam or by a shaft and tunnel constructed below it. With the weir overflow the surplus water passes down a smooth or stepped dam face into a stilling basin, where some of its energy is dissipated. For supply purposes draw-off pipes are usually installed at three different levels in a valve or draw-off tower, often located beside the spillway shaft. A new type of draw-off tower has been used at the Tryweryn Reservoir in North Wales, consisting of a system of concrete syphons controlled by compressed air (10).

River Intakes

Water may be extracted from a river in a number of ways, of which the most usual is a side intake weir constructed along the bank of the river, possibly in conjunction with a weir across the river. Other methods include a floating pontoon intake carrying pumps or a piled crib set in the river bed.

The water passes through a screening chamber usually containing

vertical bar screens in duplicate before entering the pump well, from whence it is pumped to storage reservoirs. River intakes suffer from silting and so it is customary to provide for water to be washed backwards through the pipework on occasions to force accumulated silt out from the intake into the river channel.

Wells and Boreholes

Boreholes are usually cheaper than wells, can be constructed to greater depths and are more speedily provided. Boreholes are usually drilled by 'rotary' or 'percussion' methods. In the rotary method, a hollow steel cylinder with a cutting edge is rotated causing a core of rock to enter the cylinder, in which it is held and subsequently raised to the surface. In the percussion method, a chisel of a width equal to the diameter of the bore is forced up and down in the borehole, pounding the rock into fragments, which are subsequently removed by washing out with water from the boring rods or baling out with a cylinder having a flap valve at its lower end. The upper part of a borehole is lined for a depth of 20 to 100 ft with a steel lining to prevent surface pollution. If the sides of the lower part of the bore were very soft, it would probably be necessary to insert slotted linings to give support, but at the same time permit the entry of water.

It is usual to first drill a trial borehole on the site and to conduct a pumping test to ascertain the probable yield. The flow is continuously measured throughout the test by passing it through a tank with a weir outlet and thence to a natural watercourse a sufficient distance away from the site.

It is customary to provide at least two boreholes, often adjacent to one another and interconnected below the lowest pumping level, so that an additional pump can be installed as a standby. The pumping equipment in boreholes usually consists of vertical spindle centrifugal pumps or submersible pumps. Vertical spindle pumps have a long life and efficiency but they are expensive, require housing and take several days to remove and install. Submersible pumps are unsuitable for pumping large outputs against low heads, but are relatively cheap, require no housing and can be removed or installed in a few hours.

A well may give a greater yield of water than a borehole drilled on the same site, on account of the greater area of entry for water provided, and its greater size permits the installation of all necessary pumps and control gear. Deep wells are, however, extremely costly. It is usual to form *adits* or headings, about 5 ft wide $\times$ 6 ft high and sloping slightly towards the well, through strata containing water-bearing fissures and,

if possible, across the line of flow of underground water, to increase the yield of the well. It is desirable to construct the headings in hard ground to avoid the need for support to roof and sides (2).

WATER RESOURCES ACT, 1963

The main purpose of this Act is to extend the duty of the Minister of Housing and Local Government under the Water Act, 1945, in the formulation of a national water policy, so as to include measures for augmenting, re-distributing and transferring water resources and to provide for this policy to be executed by river authorities and the Water Resources Board established under the Act.

River authorities are required to carry out periodical surveys (sec. 14), to prepare hydrometric schemes (sec. 15), to investigate water in underground strata (sec. 18) and to fix minimum acceptable flows for inland waters in their areas (sec. 19).

River authorities control the abstraction and impounding of water from any source of supply, and in future most persons cannot abstract water except with a licence granted by the river authority (secs. 23 to 35).

Charges are made for licences to abstract or impound water and river authorities are empowered to make special agreements with regard to charges for water for spray irrigation (secs. 57 to 64).

The control of pollution is extended to include discharges into underground strata (secs. 72 to 75). River authorities are also empowered to take emergency measures in the case of pollution, to take various steps to improve the quality of water, as a means of securing the proper use of water resources, and to make byelaws for the protection of water resources (secs. 76 to 79).

WATER PURIFICATION AND SOFTENING

Water authorities are required to provide an adequate supply of pure and wholesome water. Some form of purification and possibly softening of raw water is needed to ensure this. New standards of drinking water have been published for international adoption by the World Health Organisation, on the grounds that improvement in water quality could be achieved if treatment processes were made comparable and stricter control would enable avoidance of outbreaks of water-borne disease (3).

Natural water contains various impurities in suspension or solution. Rainwater, which is the purest form of natural water, dissolves carbonic

acid gas in its passage through the atmosphere. This results in a solvent action on calcium carbonate contained in limestone, chalk and other minerals, and on other compounds from rocks and soils. Natural waters also contain silica, sometimes iron, and in moorland districts will be acid in reaction. River waters can contain impurities from sewage works and industrial effluents. In addition, various forms of bacteria and other living organisms will be present in the water. Each of the various purification processes will now be considered.

Softening

Waters which readily give a lather with soap are termed 'soft', while those which do not are described as 'hard'. Hard waters result in a wastage of soap and detergents and can have harmful effects in many industrial processes. Hardness caused by the presence of bicarbonates of calcium and magnesium can be removed by boiling and this is known as 'temporary hardness', while sulphates, chlorides and nitrates of calcium and magnesium are not removable by boiling and produce 'permanent hardness'. Clarke's scale is often used as a measure of hardness.

There are two main softening processes:

- (1) Chemicals are added to the water which change the hardness compounds so that they become insoluble and are precipitated. Lime is usually added to remove the temporary hardness and soda ash to remove the permanent hardness. Mixing plant is needed for this purpose followed by upward-flow coagulation tanks, where the suspended particles are coagulated or bound together, prior to settling out or removal by filters of the rapid gravity type. A large amount of sludge is produced by this process and is usually disposed of by drying in lagoons and selling to farmers, if possible. Sludge disposal is becoming a problem and the Fylde Water Board are freezing sludge to reduce its water content.
- (2) 'Base-exchange' methods may be used, whereby the actual form of the hardness compounds is changed so that they are no longer harmful. The calcium and magnesium are 'exchanged' for sodium by passing the water through 'zeolite', which is periodically regenerated by passing brine solution through it in the reverse direction.

The equipment is similar to that of a pressure filter, consisting of a steel cylindrical tank of about 10 ft diameter containing about 4 ft of zeolite on supporting layers of graded gravel. The bulk of the zeolite used today is a synthetic manufactured material. It is an extremely simple and efficient process but is unsuitable for use with turbid water.

Filtration

Filtration is a process for removing impurities from water and is frequently accompanied by sedimentation, with or without the use of coagulants. The larger impurities can be separated by fine screens or settlement in tanks, microscopic or colloidal impurities can be removed by filters and those held in solution can be treated with chemicals and then be separated by filters. These processes are particularly necessary when using river water.

Preliminary Processes. Fine screening can be carried out with endless band or rotating drum screens perforated with about $\frac{1}{4}$ in. diameter holes. An alternative is to use micro-strainers, which are revolving drums of stainless steel wire fabric with about 80,000 apertures per in². Micro-strainers are particularly useful for dealing with water (as from lakes) which contains plankton or algae, and are replacing sedimentation tanks to some extent.

Sedimentation or settling tanks are designed to reduce the flow of water so as to cause the suspended solids to settle to the bottoms of the tanks, where they can be removed by scrapers or suction pipes. Circular-shaped upward flow tanks are the most efficient.

Colloids take many days to settle because of their very low weight, and their inability to coalesce because they all carry the same electrical charge. The addition of chemicals, such as alum or sodium aluminate, neutralises the charge on the colloids and enables them to combine and settle at a reasonable rate, termed 'coagulation'.

'Slow' Sand Filters. Filters perform both a straining and a bacteriological action and play an important part in the purification of water supplies by removing suspended solids, turbidity and colour. The first type introduced in the last century are known as 'slow' sand filters, as the rate of filtration through them is quite slow. They are usually constructed of large concrete tanks or beds containing 2 to 3 ft of sand, on which a purifying surface or 'schmutzdecke' is formed, supported by shingle over porous under-drains, which discharge the filtered water into collecting channels. When the sand requires cleaning, the bed is drained of water and the top $\frac{1}{2}$ in. to 1 in. of sand removed. This type of filter is expensive, requires a large area and is unsuitable for turbid waters.

'Rapid' Gravity Filters operate at about 20 times the rate of 'slow' sand filters. They are usually about 25 ft long $\times$ 15 ft wide with 18 in. to 30 in. of graded sand, supported by a graded pebble bed over a series of

collecting pipes. The enclosing concrete tanks are normally about 10 to 12 ft deep to allow for 6 to 8 ft of water over the bed of sand. The filter is cleaned by 'backwashing' with air and water passed upwards through the bed.

The normal rate of filtration with this type of bed is about 70 to 80 gal per ft² of bed per hour. Anthracite and activated carbon have both been used on 'rapid' gravity filters in place of sand.

Pressure Filters consist of steel cylindrical tanks about 7 ft in diameter, containing a graded sand bed 18 in. to 36 in. thick supported by a graded gravel bed, over collecting pipes or tiles. The tank is kept filled with water under pressure, with an air release valve provided at the top of the tank for release of trapped air. Cleaning is carried out by 'backwashing' as for 'rapid' gravity filters.

This type of filter has the great advantage of maximum flexibility in its siting and the omission of sedimentation, but it has a number of disadvantages in operation (2).

Chlorination

The surest way of removing bacteriological contamination in raw water is by treating it with chlorine, and the bulk of public water supplies are chlorinated by one method or another.

One method is known as 'break-point' chlorination, in which the ratio of chlorine to ammonia compounds exceeds 5 to 1 and free chlorine is formed. This method results in a reduction of chlorine taste and odour troubles and sterilisation is quicker and more effective. Another system is that of super-chlorination and dechlorination, whereby the water is dosed with a larger quantity of chlorine than the normal condition of the water warrants, and this can effectively deal with any sudden and heavy pollution of the water, as may occur with river water after a heavy storm. After the appropriate contact period, the water is dechlorinated by the injection of sulphur dioxide to leave the requisite residual chlorine in the water supply. This is an extremely effective method and is very popular in practice.

Chlorine is normally obtained as liquified gas in cylinders or drums. The chlorine is injected into the water supply through a chlorinator, which reduces the pressure of the gas as it leaves the cylinder, passes it through an orifice at a rate controlled by the pressure across the orifice, mixes it with a small quantity of water to form a concentrated chlorine solution, and then feeds it into the supply through an injection point. The best point of application is just upstream of a weir or venturi tube,

where the turbulent state of the water will assist with the mixing of the chlorine.

All reasonable precautions should be taken to prevent any possibility of contamination occurring at the waterworks, as outlined in the Ministry of Health Memorandum (4).

Fluoridation

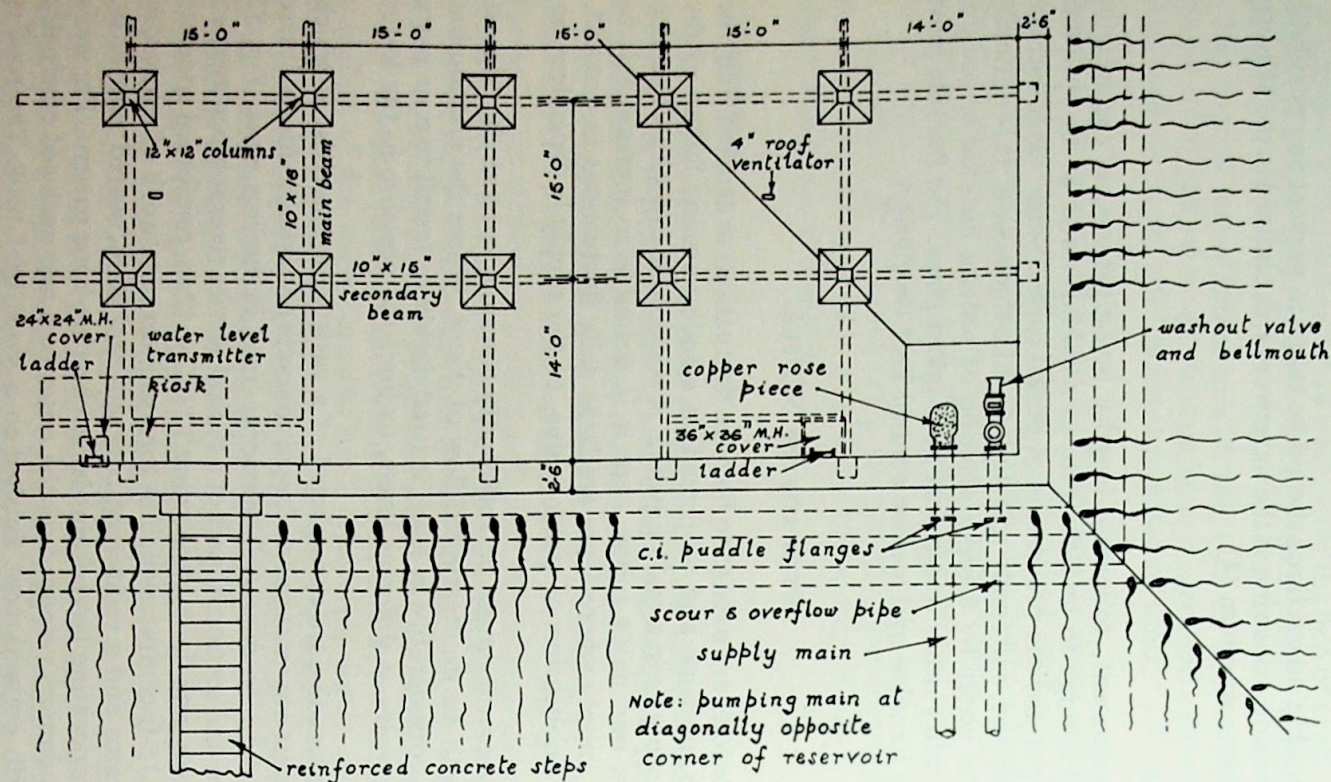
The Government, following lengthy investigations, is encouraging water undertakings to add fluoride to drinking water at an optimum level of 1 ppm, for the prevention of dental caries. Some water authorities are, however, extremely reluctant to take this action. It is normally added to the water by using a solution of sodium fluoride or sodium fluosilicate, after other treatments have taken place. The fluoride must be carefully handled and a close control kept on dosage.

STORAGE OF WATER

Service reservoirs are needed to balance fluctuations in demand from the distribution network and to provide a standby against failure of the source of supply or in a main pipeline. A reasonable capacity for service reservoirs is one day's supply, but it is desirable to increase this to three days' supply where there are large daily fluctuations in demand, there is no duplication of trunk mains, or the supply is dependent on pumping.

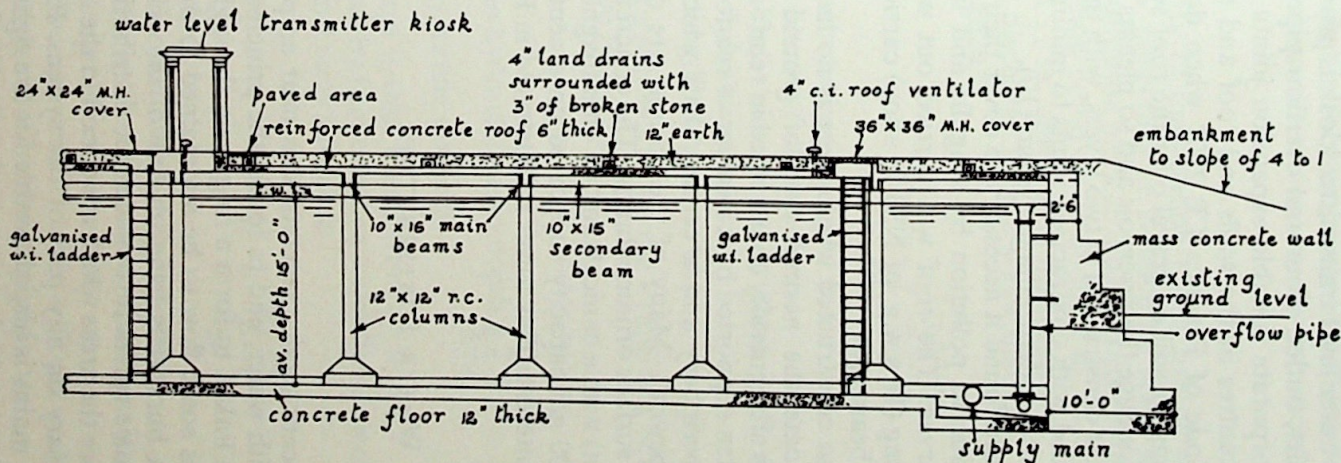
Service reservoirs must be sufficiently elevated to serve the highest buildings with an uninterrupted flow of water. Where the distribution area varies considerably in level, it is advisable to install two or more service reservoirs at different levels, to limit the pressure in the lower areas.

Service reservoirs are constructed of a variety of materials, of which the commonest are mass or reinforced concrete or a combination of these two, but some introduce embankments lined in various ways. Fig. 52 shows a plan and section of part of a typical service reservoir constructed of a 12 in. concrete floor, supporting 12 in. $\times$ 12 in. reinforced concrete columns at 15-ft centres, which in turn support a network of reinforced concrete beams and a reinforced concrete roof slab covered with 12 in. of soil, incorporating land drains laid to herring-bone pattern. The walls are of mass concrete stepped on the outer face and enclosed externally with an earth embankment finished to a slope of 1 to 4. The roof is provided with ventilators at about 50-ft centres and manhole covers



PART PLAN

FIG. 52. Service reservoir (Part Plan).



PART SECTION

FIG. 52. Service reservoir (Part Section).

varying from 24 in. $\times$ 24 in. to 36 in. $\times$ 36 in. in size for purposes of access at vital points. A water level transmitter kiosk is provided and the pipework consists of inlet, outlet, scour and overflow pipes.

It is essential to incorporate suitable expansion joints of rubber or P.V.C. at about 30-ft centres in the walls and roof and to follow the recommendations in Code of Practice CP 2007 when designing such structures (5). A covering of soil or gravel over the roof serves as insulation and helps to camouflage the reservoir and so pleases the planners. The reservoir floor is best constructed in two layers, with the upper layer reinforced and subdivided with contraction joints to minimise cracking, coupled with an adequate underdrainage system (10).

The Fylde Water Board found it necessary to cover their open service reservoir at Weeton, due to pollution by seagulls and infestation by shrimps and midge larvae. The roof was carried out with troughed aluminium sheet vaulting (16 s.w.g. of NS3-H alloy) carried on precast concrete columns and beams (6).

Water towers are also constructed where there is no land sufficiently elevated to accommodate the normal type of ground level service reservoir. Water towers are generally constructed in reinforced concrete, with a circular tank often supported by a number of reinforced concrete columns around the periphery and a central shaft which houses the access ladders and pipework. Many of the designs are quite pleasing with skilfully executed surface ornamentation. The concrete water tower at Hollingbourne (Kent) with a conical tank of 'champagne-glass' shape, 70 ft high and of 60,000 gal capacity supported on a central shaft, has aroused considerable interest. This tower is illustrated in Plate VII.

WATER DISTRIBUTION

Mains Layout

It is desirable to locate service reservoirs as near as possible to the area to be supplied with water, and to locate the principal distribution mains so that they are linked to form a ring main through the distribution area. This enables some flow to be maintained to the distribution area in the event of a burst occurring on one of the principal mains. Ample provision of sluice valves throughout the distribution network is also advisable, to reduce the areas which are cut off in the event of repair work becoming necessary on any part of the system. Extensive cross connecting of smaller mains is also desirable for fire fighting purposes.

Air valves are provided at high points in the distribution area for the

emission of any air which becomes trapped in the mains. Washout valves are needed in the low points or hollows for periodically scouring out sediment from the mains, usually into nearby watercourses.

Pipe Sizes

The majority of distribution mains are of 4 in. or 6 in. diameter, although 3-in. pipes may be suitable for small housing sites or culs-de-sac. Main distribution pipes leading into the centre of the area or through it as a ring main could be of about 9 in. diameter. Trunk mains are usually about 12 in. upwards in diameter.

The actual discharge from a water main can be calculated from the following formula:

$$Q = \sqrt{\frac{(3d)^5 H}{L}}$$

where Q = discharge in gal per min.

d = diameter of main in in.

H = head over length of main in ft (vertical component of hydraulic gradient)

L = length of main in yd.

Another alternative is to use the Crimp and Bruges formula, when the velocity can be found from:

$$V = 124^3 \sqrt{m^2} \sqrt{i}$$

where m is the hydraulic mean depth $\left(\frac{d}{4}\right)$

and i is the hydraulic gradient.

The discharge is then found from $Q = AV$.

The head lost by friction when water flows through a circular pipe can be found from Darcy's formula:

$$H = \frac{FLV^2}{2gd}$$

where H = friction loss (ft head of water)

f = Darcy's coefficient—a dimensionless number

L = length of pipeline in ft

V = average velocity of flow (ft per sec)

d = internal diameter of pipe in in.

g = 32.2 ft per sec²

The head loss through fittings is found from

$$H = \frac{kV^2}{2g}$$

where k varies with the type of fitting, e.g. 0.75 for a medium radius 90° bend, 1.5 for a right-angle tee and 10 for an open screwdown valve.

In practice pipe flows are often obtained from charts giving flows in gal per day.

Pipe Materials and Corrosion

For many years the majority of water mains were laid in cast or spun iron pipes, with spigot and socket joints caulked with lead, in three classes—B, C and D, according to the working pressure required (400, 600 and 800 ft head). Various alternative joints have been developed over the years, mainly using bolts and couplings. One of the more recently introduced joints which is extremely simple and effective is the 'Tyton' or 'O' ring joint, which uses pipes with chamfered spigots which have a special lubricant applied to them before they are driven home, a rubber gasket or ring sealing the space between the pipes. Pipes with flanged joints are normally used for exposed pipework and suspended mains, such as in boreholes, but the cost of flanged pipes is about double that of spigot and socket pipes. 'Ductile-iron', which has been treated with magnesium, is sometimes used for water mains, as it possesses greater mechanical strength and ductility.

A variety of alternative materials are now available for use in water mains, such as steel and prestressed concrete in the large diameters, asbestos cement for intermediate diameters and plastics for small diameters.

Steel Pipes in the larger diameters are made from steel plate bent to a circular shape and with the edges lap or butt welded. Smaller pipes, up to 12 in. diameter, are of 'seamless' manufacture. Steel pipes can be coupled or have socketted joints for running with lead or welding. They are normally protected externally against corrosion by a bituminous sheathing reinforced with glass fibre. A spun lining of bituminous compound or concrete is applied internally.

Prestressed Concrete Pipes are made by tensioning high tensile wire wound spirally around a cylindrical core of concrete or steel. These are cheaper than steel pipes for the largest diameters and pressures and are highly resistant to corrosion, but difficulties arise when new connections

are required to existing mains. Joints can be of steel spigot and socket, prestressed concrete collars with a rubber ring, or metal couplings.

Asbestos Cement Pipes are made in diameters up to 18 in. from Portland cement and asbestos fibre, and are dipped in cold bitumen at the end of the manufacturing process. They are highly resistant to corrosion but are rather brittle, need careful handling and should not be laid below roads carrying heavy traffic. Joints are normally formed with double collars and rubber rings, or metal couplings.

Plastic Pipes of high-density polythene or unplasticised P.V.C. are now used quite extensively for distribution mains in the 3 in. to 6 in. diameter range, where working pressures are not excessive. They are light, available in lengths of 20 ft, are readily bent and can be quickly and easily jointed above ground. Furthermore, they are highly resistant to corrosion, will successfully withstand settlement and offer little resistance to flow.

For larger diameters (obtainable up to 72 in.) pipes of glass fibre reinforcement, often with flanged joints, have been used successfully. They are made of a mixture of glass fibre and epoxy or polyester resins, and are often provided with a P.V.C. lining to increase corrosion resistance and give a smooth internal surface (10).

Corrosion of Pipes is a matter of some consequence as it has far-reaching effects. The internal corrosion of steel and cast iron pipes can result in tuberculation of the metal or the supply of 'rusty' water, resulting in a reduction in the carrying capacity of pipes and problems in laundries and other industrial processes. Externally, protective coatings are needed to guard against attack from sulphide and sulphate bearing clays and made-up ground containing cinders, clinker and slags. Fortunately a variety of protective coatings are available—cemented, electro-deposited, hot-dipped, molten-metal sprayed, powdered and wire sprayed, etc.

Considerable progress has also been made in the technique of applying cathodic protection to water mains. This method uses an induced electric current, to reduce the rate of corrosion of a metal in contact with an electrolyte, by making the whole of the metal the cathode of the induced current. If the electric current can be prevented from leaving the structure at the anodes, then no corrosion can take place (7).

River Crossings of moderate spans are normally constructed as a self-supporting pipe-bridge carried on abutments. In some cases steel pipes need strengthening with stiffening ribs. In other cases, it is common

practice to excavate a trench in the river and sink a pre-formed welded steel pipe into the trench (10).

Waste Water Prevention

It is essential that the quantity of water leaking from mains and services should be reduced to an absolute minimum. Two principal methods are employed for the detection of waste, both based on the premise that the majority of flows between the hours of 2 a.m. and 5 a.m. represent waste.

(1) **Sounding**, in which the inspector partially closes the stopcock serving each property in turn with a 3 ft long stopcock key and listens at the handle end of the key. In cases where a suspicious amount of flow is heard the matter will be subsequently investigated on the premises during daytime.

(2) **Waste-water meters** are special meters housed in underground pits and usually located on principal distribution mains to record flows through the night. During the night, at pre-arranged times, valves will be closed to progressively shut-off sections of the distribution area. The meter recordings will pinpoint any sections which are subject to heavy night flows and which justify further investigation.

Maintenance Problems

Consideration will now be given to some of the more important aspects of maintenance work in connection with water supply systems.

Connections for consumers to existing mains are usually made under pressure with a suitable tapping machine, which is chained to the main. A drill bit bores and taps a hole in the pipe wall, the spindle head of the machine is revolved and a ferrule screwed into the hole.

Meters are installed on the communication pipes to industrial and the larger commercial premises. The type of meter installed will be determined by the flow rate which will operate.

Semi-positive meters are used to record the smaller flows, of which the most commonly used variety is the rotary piston meter, in which a freely moving hollow cylinder is turned by the flow of water and opens and closes inlet and outlet ports in the process.

Inferential meters are more suitable for larger flows and contain a specially designed propellor blade or vane, which is rotated by the flow of water.

Metered supplies are charged on the basis of water consumed, a typical charge being about 3/- per thousand gallons; the meters are normally read quarterly and the readings entered in suitably prepared meter books, with a page for each property or meter. Faulty meters must be replaced forthwith and the last reading calculated on a *pro rata* basis. Charges for unmetered supplies are based on the net annual value of the premises for rating purposes, but water for building work is still frequently charged at an excessively high rate per £100 of the contract price.

Repairs to burst water mains are required at the most inopportune times in even the best regulated of water undertakings. The only remedy is to have an efficient organisation of skilled and experienced personnel with a good supply of spare pipes and fittings always available. A supply of stencilled notices ready for distribution in an emergency, if supplies have to be cut off while repair work is in progress, can be very useful and helps in the maintenance of good relations with the public.

Frozen Water Pipes can often be thawed out by passing an electric current through them from suitable thawing equipment, consisting of a transformer with a primary winding supplied from the 240V supply, a secondary winding giving a heavy current up to 500 amp at a low voltage, with heavy leads and clamps to connect to the piping or stopcocks. A control switch is also usually provided to give a range of current loadings and the equipment is operated for about 5 min only in a 20-min period. The applied voltage is about 50V with a current of several hundred amp.

The electric current flows through the pipes thawing the ice immediately adjacent to the pipe, and the remainder is thawed by the passage of water past it from the supply. Immersion heaters should be unearthed when thawing out domestic services. This process cannot operate with plastic or asbestos cement pipes.

Water undertakings usually circulate all consumers with notices about frost precautions, in the autumn before the really bad weather sets in. Consumers are usually requested to locate their stopcocks and check that they function satisfactorily, to protect all exposed pipes, keep plugs in outlets of sanitary appliances, stop taps from dripping and to maintain some background heating in severe weather. A few years ago Nottingham water department had to deal with over 11,000 burst pipes in one winter. The amount of wasted water in these circumstances must

be enormous, apart from all the inconvenience caused to occupiers of property.

Tracing Buried Pipes can be carried out with a pipe and cable tracer, a small portable battery-operated device consisting of a transmitter, a receiver with a detector wand and a rod transmitter for insertion in pipes. If the pipe to be traced is of metal the electric impulses generated by the transmitter will be picked up by the pipe and the operative at ground level will receive signals through the earpiece attached to the receiver, when he holds the detector wand over the pipe. With P.V.C. and asbestos cement pipes it is necessary to insert the rod transmitter into the pipe.

Water Analyses

These should be undertaken at regular intervals to ensure that the water is free from contamination and in every respect fit for human consumption.

A physical examination will give information on deposits, turbidity, odour and colour. Turbidity should not exceed 5 units (Hayen).

A general chemical examination will probably give the *pH* value (preferably above 7.0), and amounts of free carbon dioxide (not to exceed 20 ppm), free ammonia (not to exceed 0.05 ppm), nitrogen, temporary and permanent hardness (on Clarke's scale or in ppm), permanganate figure, alkalinity, total solids and poisonous metals.

Mineral analysis will generally indicate the amounts of calcium, magnesium, carbonate, chloride, sulphate, nitrate, iron, sodium and fluoride in the water. A plumbo-solvency test is performed by noting the action of the water on lead in 3 days at 21°C.

The most important analysis is the bacteriological examination, for which samples should be taken once a week in laboratory prepared sterilised sample bottles. Where samples are taken from taps, these must be sterilised by flames from burning methylated spirit for a minute or two, and then water should be run-off from the tap for a further 2 or 3 minutes before the sample is taken.

A Ministry of Health report states that all treated water supplies should be free from any coli-aerogenes bacteria in 100 cm³ of water (8).

The results of a typical bacteriological examination of a water sample follow.

- (1) Plate Count—Yeastrel Agar, 24 hr at 37°C aerobically
per ml

(2) Probable number of coliform bacilli, MacConkey, 2 days at 37°C
.....0 per 100 ml

(3) Probable number of Bact. coli (type I)0 per 100 ml

Note: (1) This is an indication of the numbers of bacteria which thrive at body temperature and are likely to be of faecal origin.

(2) This indicates the numbers of bacteria present of the coli-aerogenes group.

(3) This gives a positive indication of the degree of faecal pollution.

On receipt of an adverse bacteriological examination, it is customary for the water undertaking to take immediate precautionary action. This procedure could take the following lines:

- (1) Step up the chlorine in the supply to 0.3 ppm.
- (2) Inform the Medical Officer of Health.
- (3) Inspect reservoir and check chlorinating plant.
- (4) If the bad sample was taken from a consumer's tap, arrange a resample from another tap off the same main and from the supply from the reservoir.
- (5) If unsatisfactory results are obtained on re-analysis, take immediate steps to trace source of infection and ensure that free chlorine is maintained in all supply mains.

Water Bye-laws

Most water undertakings operate bye-laws based on the model bye-laws issued by the Ministry of Housing and Local Government (9). The main purpose of these bye-laws is to ensure that standards of plumbing are used which will not lead to waste, undue consumption or contamination of water. Water undertakings often issue lists of approved materials and fittings to be used in their areas, to prevent water wastage, and may issue lists of 'approved' plumbers, to maintain satisfactory standards of workmanship and materials.

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CHAPTER NINE

Traffic Engineering

THIS subject has assumed tremendous importance in recent years and a vast number of technical papers and publications have been issued. The ever-increasing number of vehicles, the fast rising intensity of urban traffic congestion and the colossal number of road accidents call for radical and costly long-term measures to cope effectively with the vast problems created by the motor vehicle.

This chapter endeavours to encompass the wide field of activities covered by this subject and concludes with a substantial list of references, from which detailed information on the various aspects can be obtained.

TRAFFIC FLOW

'Traffic flow' has been defined as the number of vehicles which pass a fixed point in unit time. It is sometimes referred to as traffic volume and is, without doubt, one of the most important characteristics of a stream of traffic (see reference 1 at the end of this chapter).

Traffic flows are usually measured by hand or by automatic counters at selected points on a road network. Turning flows at junctions are almost invariably carried out manually. When investigating the performance of roads or pavements it is desirable that the amount of the wheel loads of the vehicles passing over them be determined. The Road Research Laboratory has developed apparatus which automatically weighs vehicles as they travel along the road at normal speeds.

The degree of accuracy required on a traffic count will vary with the purpose of the count. Errors of up to 10 per cent would not be excessive for all normal purposes and errors of from 10 per cent to 25 per cent would still be permissible, if the figures were only required as a rough

guide. A count of vehicles from 6 a.m. to 10 p.m. on a successive Friday, Saturday and Sunday would fall within the latter category. A wide variety of counting methods are available.

It is often necessary to determine the peak hourly flow in a specific road. For this purpose the three months which carry the highest average hourly flow should be decided upon and also the hour concerned. Preliminary counts may be necessary if this cannot be decided on the basis of experience. Finally, counts will be carried out for a sufficient number of the 13 peak hours, throughout the 3-month period.

The Ministry of Transport has carried out traffic counts at 50 selected points since 1956, from which daily totals of motor vehicles are obtained. Manual counts are also carried out at regular intervals at each of these points to give information on the various classes of vehicle. These counts show the annual trends in numbers of vehicles passing the selected points and it is estimated that between 1956 and 1963, the motor vehicle/miles on trunk and classified roads increased by 66 per cent (8 per cent compound per year). The heaviest traffic flows are normally experienced during the months of June, July and August. Week-end rural traffic has the largest seasonal variation, while weekday urban traffic has the least.

It is exceedingly difficult to forecast future numbers of vehicles, as the rate of increase of numbers of vehicles is closely related to the rate of economic expansion (e.g. real income per head) and this has not proceeded at all smoothly over the post-war years. In 1960, the proportion of vehicles per head in this country as compared with the United States, was about 45 per cent. Buchanan estimated an increase in the number of vehicles in Great Britain from $10\frac{1}{2}$ millions in 1963 to 18 millions in 1970, 27 millions in 1980 and 40 millions in 2010 (2).

Intense urban traffic congestion has resulted in extremely low traffic speeds, even given as low as 6 mph for some central districts of London and Glasgow (3). The author suspects that speeds are much lower in the central areas of many cities in this country during peak traffic periods. The cost of this appalling congestion has been estimated at about £300 million to £600 million a year, depending on the valuation placed on non-working time. Accidents are estimated to involve the community in losses amounting to about £175 million a year, quite apart from the tragic human suffering that results (1).

Approximately 25 per cent of all traffic in this country is carried by 1 per cent of the roads and some 60 per cent of the traffic by 10 per cent of the roads. These figures indicate an extremely unbalanced incidence of road traffic on our highway network.

Apart from undesirable noise and fumes, loss of environment, danger to road safety and cost of traffic delays, urban traffic congestion must

have a detrimental effect on land use and land values. Some shoppers will eventually tend to leave the congested central areas of the larger towns and cities to make their purchases in alternative shopping centres, where parking facilities are available in close proximity to a compact shopping area.

ROAD TYPES AND CAPACITIES

Roads are primarily classified according to their function. The following basic classifications are given in the 1946 Ministry of Transport report (4).

Arterial Roads

Roads serving the country as a whole, or a region of the country, and linking up the main centres of population or the various regions.

Through Roads

Roads carrying traffic having its origin outside the town, and its destination inside the town, or vice versa.

Local Through Roads

Roads carrying traffic having its origin in one area of the town, and its destination inside the town, or vice versa.

Local Roads

All other roads in the town except development roads.

Development Roads

Roads the primary function of which is to provide frontage for the development of land.

The plans for cities produced during the post-war years generally introduced a series of intermediate and outer ring roads, intended to give relief to the city centre and to connect the outer districts of the city.

The latest Ministry of Transport memorandum (5) emphasises the need for by-pass or relief roads around existing towns, to divert through traffic from the central business and shopping areas and so assist in the

preservation of the local character of the area and maintenance of general road safety.

Buchanan in *Traffic in Towns* (2), develops the idea of a 'hierarchy' of distributors, whereby important distributors (primary) feed down through distributors of lesser category (district and local) to the minor or access roads, which give access to buildings.

The road pattern planned for Cumbernauld New Town is putting Buchanan principles into practice and the following road types have been introduced (6):

Regional Trunk Roads

These are designed to rural motorway standards by the county councils.

Town Radial Roads

These roads will carry daily peak hour flows ranging from 1,000 to 4,000 mixed vehicles per hour. They will all contain dual carriageways with movement on or off restricted to the near side, and with no associated footpaths or frontage development, no parking and no bus stops, but with a geometric design speed of 50 mph on through routes. These roads will be depressed near housing areas.

Primary Distributors

These roads are designed to carry about 1,200 mixed vehicles per hour and their main function is to distribute traffic to the various development areas from the nearest interchange point with the radial system. A three-lane carriageway was adopted on the understanding that priority of use of the central lane would be given to turning traffic at junctions. This arrangement has advantages over the use of dual carriageways, as it occupies less land, costs less, creates less of a barrier between building developments on either side and drivers tend to use it for the shortest possible distance, thus making the fullest possible use of the radials. Prohibition is maintained of frontage development, footpaths, surface pedestrian crossings and parking.

The design capacity of a 33-ft carriageway consisting of two running lanes and one turning lane, has been taken as 1,000 mixed vehicles per hour in each direction.

Local Distributors

All environmental housing zones are individually served by their own connection to the primary distributor roads. Where daily peak hour

flows exceed 300 vehicles per hour, the area is served by a frontage free local distributor which, in turn, feeds the service roads. The local distributor could be either a long cul-de-sac, up to 1,000 ft in length, or a loop road with two connections to the primary distributor.

The normal arrangement for local distributors is to use a 24 ft wide, two-lane, two-way carriageway, which with occasional parked vehicles will have an estimated total capacity of 300 to 500 mixed vehicles per hour (total-both directions of flow). *Note:* it seems likely that the maximum capacity of this class of road will be in excess of the figures quoted.

Service Roads

The service roads are planned as short culs-de-sac, giving dispersed penetration into the housing areas, so that no house is more than 50 yd from the nearest service road. The daily peak hour flow will not exceed 300 vehicles per hour and frontage development is permitted on these roads.

The normal provision for service roads consists of an 18 ft wide, two-lane, two-way carriageway, which with occasional parked vehicles will have a maximum capacity of 300 mixed vehicles per hour (total-both directions of flow).

In all but the service roads, the traffic function of the road is paramount and only in the case of service roads is frontage development permitted.

Road Capacities

A useful table, indicating the practical capacity of a variety of types of urban road with varying widths of carriageway, is included in the Ministry of Transport memorandum (5).

The effective traffic capacity of a road between junctions is reduced by a number of factors, such as gradients exceeding 1 in 20, use of road by buses, parked vehicles and provision of pedestrian crossings (7). The capacity of a road or intersection is often specified in terms of *passenger car units* (pcu). The following passenger car unit equivalents have been suggested for the various types of vehicle (1).

	Urban streets	Rural roads (Min. of Transport)
Cars and light vans	1.0	1.0
Medium commercial vehicles	1.75	} 3.0
Heavy commercial vehicles	2.5	
Buses and coaches	3.0	3.0
Motorcycles	0.75	1.0
Pedal cycles	0.33	0.5

The Ministry of Transport has given the following hourly capacities for peak hour traffic on rural roads.

<i>Carriageways</i>	<i>Passenger cars per hour</i>
Two-lane	up to 450
Three-lane	450 to 900
Dual two-lane	900 to 2,500
Dual three-lane	over 2,500

ROAD LAYOUTS

It is inevitable that severe traffic congestion should arise in town and city centres as, with few exceptions, little has been done to change the road patterns to cope with present-day conditions.

Many city councils are engaged in constructing ring roads of dual carriageways, with grade separated junctions, around the outer reaches of the cities, to intercept through traffic and pass it along high speed motorways until it reaches the exit road which it requires. In other cases wide rings road are being constructed around the inner core of the city (containing the main shopping, office and entertainment areas), to prevent traffic crossing the central area and to distribute vehicles into multi-storey car parks.

Adopting the Buchanan principle of safeguarding environment, and preventing our central buildings and activities from being seriously impaired by the noise, fumes, vibration and even the very existence of vast numbers of vehicles, many local authorities are considering or implementing traffic-free shopping zones or precincts. The process of segregation of vehicles and pedestrians is now being adopted to an increasing extent in the layout of housing areas, with various forms of 'Radburn' development. In these schemes, which are dealt with in more detail in Chapter XI, the main access ways to the houses from schools, shops, etc. are by paved footpaths. Distribution roads skirt the housing areas and give access for tradesmen and to blocks of garages. The footpaths negotiate these roads by subways.

The 'Radburn' layouts offer a radical departure from the orthodox housing layout of houses fronting on to 16 ft or 18 ft wide through roads and 13 ft or 16 ft wide culs-de-sac. Many local authorities are now increasing the width of housing estate roads from 16 ft to 18 ft, or even 20 ft, where the road serves substantially more dwellings than are sited on its frontage (23).

In new and expanding towns, it is customary to provide spine roads

through industrial areas with a 30 ft wide carriageway, serving link roads often with a carriageway width of 24 to 30 ft. Rear access roads to factories should have a minimum width of 20 ft.

In some new towns, independent cycleway systems were planned to connect the industrial area and main centres of secondary education with the main housing areas. In Crawley, financial considerations prevented most of the cycleways from being constructed, but reservations of land have been made for the eventual provision of some of the more important routes. It has been found that about 20 per cent of the industrial employees cycle to work and about 50 per cent of the secondary school children cycle to school (8).

In 1964, Leicester produced its traffic plan, based on a comprehensive traffic survey and consideration of land-use and socio-economic structure with the aid of a computer. The first solution, permitting unrestricted use of private cars throughout the city, required the construction around the central area of a 16-lane elevated inner motorway with large multi-level intersections. Besides destroying the urban environment, the scheme was estimated to cost over £400 million, excluding the cost of local distributor roads, and was rejected on economic, social and environmental grounds.

The approved Leicester scheme is estimated to cost £135 million and to take 30 years to implement. It has three main elements, consisting of an inner motorway and 7 radial roads, a high capacity road network with interchange car parks and efficient public transport.

Interchange car parks will be approached from the radial roads and car drivers will complete their journey into the central area by an efficient 'integral transport system'. The car parks will be linked with suburban shopping, entertainment and sports centres.

These car parks will enable the proposed elevated inner motorway to be reduced in width to 4 to 6 lanes. This road will be 5 miles along, enclose the central area of the city and be linked with 7 radial roads (the primary distributor network). There will also be a system of secondary distributor roads.

It is proposed to introduce a unified city transport system consisting of bus services, a monorail and taxis. The buses would include a special city-centre rush-hour model in which standing only is allowed. The monorail would link the main residential areas with the city centre, and consideration has been given to a new form of taxicab—a small electrically driven model for use in the central area only.

It is further proposed that pedestrian conveyors should be provided along the heaviest pedestrian routes, either in the form of pedestrian bridges or as elevated continuous walkways down the centre of the main

shopping streets, to give a comprehensive system of pedestrian ways.

The central area would be preserved without the need to alter or remove historic buildings or widen existing streets. The twilight areas would be redeveloped comprehensively. Motor-vehicle penetration into the central area would be restricted, as the basic means of transport here would be public transport. The maximum car parking accommodation requirements have been assessed at 22,500 car spaces, serving a total population of about 450,000.

This is an imaginative plan which comes to grips with the traffic problem and secures a balance between the land uses in the city and the available traffic accommodation. It seems apparent that the 'ring and radial' system has some major disadvantages. Through traffic passes round the ring roads making a long detour, through many intersections, and is mixed with a considerable volume of mixed city traffic. Drivers are also tempted to take short cuts through the central area, probably taking the least desirable route from the traffic aspect.

The Leicester traffic plan adopts the 'tangential' system, whereby the traffic traverses the shortest route skirting the central area and there is no incentive to take a short cut through the centre. There is a reduction in the number of intersections to be negotiated and the different classes of traffic are segregated.

ROAD DESIGN

Gradients

A maximum gradient of 1 in 25 is recommended in a Ministry of Transport Memorandum (9). In hilly country it may be necessary to exceed this gradient, but the provision of an additional lane for ascending traffic is then advocated on important roads with single two-lane carriageways. A minimum desirable gradient for surface water drainage is 1 in 250 (4).

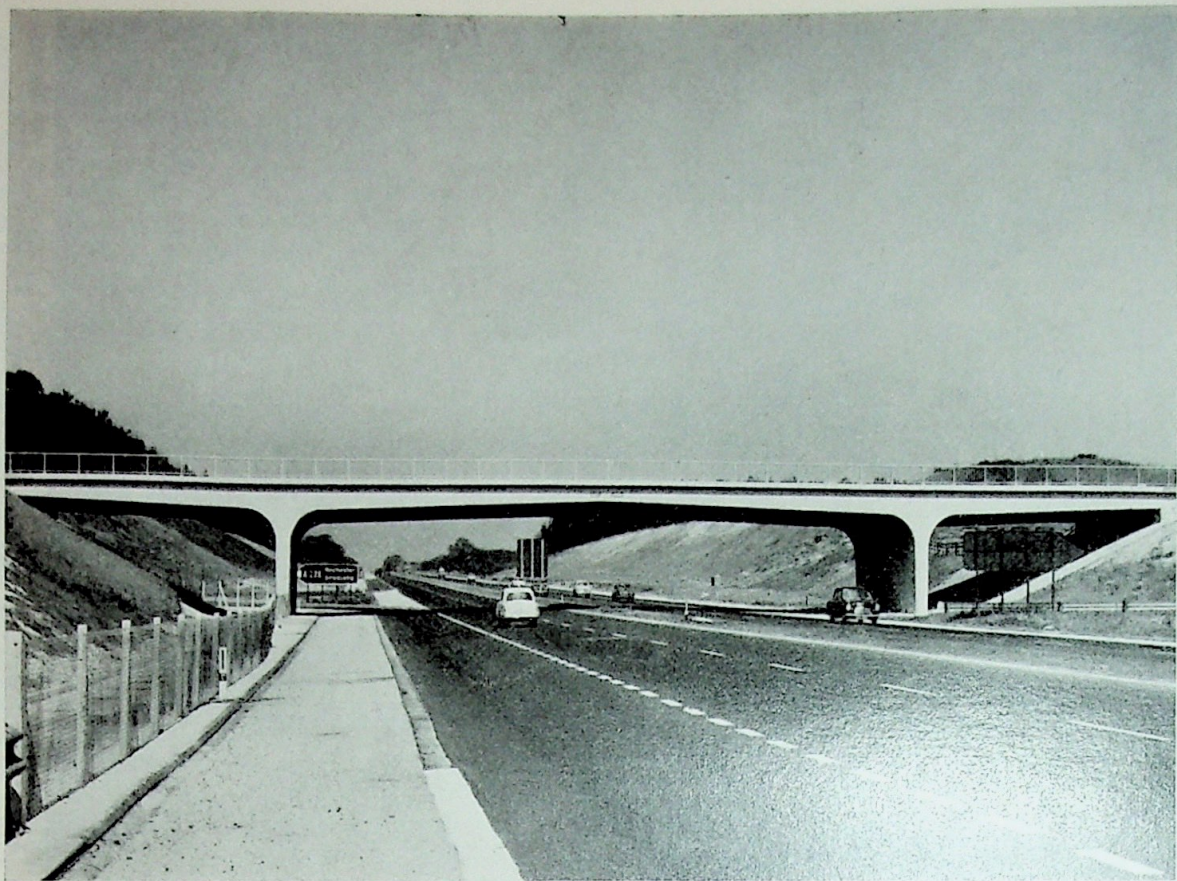
Sight Lines

The visibility from the minor road at an uncontrolled road junction, needs to be sufficient for a driver to judge satisfactorily when a gap occurs which is adequate for him to cross the streams of traffic on the major road. On urban roads this gap involves about 7 seconds travelling time, which requires a sight line of about 300 to 350 ft on the major road.

The Ministry of Transport Memorandum (5) advocates that the dis-



VII Reinforced Concrete Water Tower, Hollingbourne



VIII Motorway with bridge over, Kent

tance up the minor road from which 300 to 350 ft visibility is obtained, should be 30 ft for through minor roads, 20 ft for culs-de-sac or important private accesses and between 10 and 20 ft for less important accesses (presumably the dimensions are taken along the kerb of the major road and the centre line of the minor road).

Other Design Considerations

The Ministry of Transport Memorandum No. 780 (9) advocates design speeds of 70 mph for dual carriageways, 60 mph for 33 ft single carriageways and trunk and Class 1 24 ft single carriageways and 50 mph for other classified roads with two-lane single carriageways in rural areas. In urban areas, Crawley New Town adopted 45 mph for principal roads (8) and Cumbernauld adopted 50 mph for town radial roads, 40 mph for primary distributors, 25 mph for local distributors and 20 mph for service roads (6).

The maximum superelevation on main roads should preferably be 7 per cent or 1 in 14½ although this could justifiably be increased on down-grades and reduced on up-grades. On distribution roads, 5 per cent would be suitable dropping to 3 per cent on service roads.

At Cumbernauld the minimum radii adopted on horizontal curves are 790 ft for town radial roads, 533 ft for primary distributors, 120 ft for local distributors and 50 ft for service roads, based on the following formula (6).

$$\frac{V^2}{15R} = e + f$$

where V = vehicle speed in mph (design speed)

R = radius of curve in ft

e = rate of superelevation (ft per ft)

f = side friction factor (0.14 in case of minimum radius)

The Ministry of Transport advocates minimum radii on horizontal curves of 2,800 ft at 70 mph reducing to 900 ft at 40 mph (9).

The minimum radii adopted for vertical curves at Cumbernauld are 10,000 ft (crest curves) and 5,000 ft (sag curves) for town radial roads, 5,000 ft (crest curves) and 3,500 ft (sag curves) for primary distributors, 1,500 ft for local distributors and 800 ft for service roads (6).

The crest vertical curvature was based on the following formula:

$$K = \frac{S^2}{200 (\sqrt{h_1} + \sqrt{h_2})^2}$$

where K = rate of change of gradient (ft per 1 per cent)

S = stopping (sight) distance

h_1 = height of observer's eye above road level

h_2 = height of observed object above road level

(stopping sight distances range from 350 ft for town radial roads to 100 ft for service roads)

Sag vertical curve radii were based on the following formula:

$$f = \frac{V^2}{R}$$

where f = vertical acceleration (usually taken as 1 ft per sec²)

V = design speed (ft per sec)

R = radius of curve (ft)

ROAD JUNCTIONS

The capacity of a road network is largely determined by the overall capacity of the major road junctions. Furthermore, the majority of road accidents in urban areas occur at these junctions. For these reasons alone the design of road junctions must constitute one of the highway engineer's most important functions. The essential function of a junction is to resolve conflict between intersecting traffic streams either by grade separation, signal control or by channelling traffic into the most suitable paths for cutting or merging with other traffic streams (5). Consideration will now be given to the principal types of road junction or intersection.

'T' and Cross Junctions

The majority of road junctions in urban areas are of this type and the main deficiencies on many existing intersections are inadequate sight lines and too small a radius on the kerbs. The minimum radius on housing estate road intersections should be 35 ft, and there are some who feel that 50 ft is a desirable minimum to permit vehicles to leave the major road at a reasonable speed.

Extensive investigations in Plymouth have shown that the provision of a 'Give way' road sign, coupled with broken white lines at the junction, improves traffic conditions and reduces accidents. Where the carriageway is sufficiently wide, traffic flow can be further improved at an intersection by providing a lane for right-hand turning traffic, marked out with white lines and arrows (10).

Channelised Junctions

Further improvement can be effected by introducing some form of channelisation, which separates the different streams of traffic and provides waiting space for vehicles wishing to turn. The value of central islands as a refuge for pedestrians crossing the road should not be overlooked, and they should preferably incorporate a section with dropped kerbs to assist mothers with prams.

Roundabouts

Until quite recent times, the majority of highway engineers and town planners seemed to regard the provision of roundabouts at all major road intersections as a necessity. Most of the post-war plans of the larger towns and cities showed an inner ring road interspersed with roundabouts at the junctions with radials. The size of the roundabout was not always determined in relation to the number of vehicles it had to serve, but often by the area of land likely to be made available.

Roundabouts have a number of disadvantages:

- (1) On reaching saturation point, they become blocked and their capacity is then nil.
- (2) To cater satisfactorily for large flows of the order of 5,000 to 6,000 vehicles per hour, the central island in the roundabout would need to be about 300 ft in diameter—making for long detours and using large areas of highly priced land.
- (3) At peak periods they become difficult to negotiate.
- (4) They present a real hazard to pedestrians unless costly subways are provided under the approach roads.

On the other hand they do possess a number of advantages:

- (i) Complete interchange is made possible at the junction.
- (ii) They are reasonably safe in operation.
- (iii) Unnecessary delays are avoided during periods of light flow when movement is continuous.

Roundabouts have to be individually designed to suit the site, volume and distribution of traffic. The radius of curves at entry should be between 40 and 75 ft, with greater radii being used on the central island to give dominance to the flow of the roundabout. The best shape for the central island may well be asymmetrical, either wholly curved or a combination of straights and curves. In the design stage, it is necessary to prepare a diagram showing the volume and proportion of weaving traffic on each weaving section of the roundabout for each peak period,

making allowance for probable future increases in flow (e.g. 1959 flows + 150 per cent). Readers are referred to the Ministry of Transport Memorandum for examples of roundabout design charts and calculations (5).

Experience in Plymouth tends to indicate that where the total traffic flow at a junction is likely to exceed 3,000 to 4,000 vehicles per hour, provision ought to be made for an underpass or fly-over (10).

Traffic Signals

Where uncontrolled road junctions take heavy traffic flows, side road traffic is likely to be subjected to considerable delay and accidents and congestion result. Under these circumstances, it is usually desirable to introduce signal control of traffic. When designing traffic signal installations, it is necessary to prepare traffic diagrams, layout and phasing details and check on the reserve capacity available. Detailed information on the design of these schemes is given in the Ministry of Transport Memorandum (5).

The main advantages of traffic signals can be listed as follows:

- (1) A well designed two-phase installation has almost the same capacity as the approach roads.
- (2) The junction cannot be blocked completely, as with roundabouts under saturation flows.
- (3) Pedestrian phases can be incorporated to provide safe crossing conditions for pedestrians.
- (4) Only a relatively small area of land is needed.

There are some disadvantages, as listed below:

- (i) There is a greater likelihood of accidents, particularly front to rear collisions.
- (ii) Delays occur with light traffic flows.
- (iii) Drivers dislike having to stop.

Traffic signal installations are very flexible and, by means of time switches, it is possible to have a series of phasing combinations to suit differing traffic conditions throughout the day. In Plymouth, one installation handles 3,200 vehicles per hour at peak periods and this could probably be increased to 4,500 vehicles per hour, with the provision of three lanes on each approach (10).

No doubt, great advances will be made in traffic signal techniques in the years to come. Large road networks may well be covered by a series of traffic signals controlled by a master computer, which continuously

assesses the traffic conditions and ensures that all sections of the network are receiving their fair share of the traffic. Another system could incorporate closed-circuit television with presence detectors. Another and simpler approach is the use of linked traffic signals, whereby the 'green' times are co-ordinated at successive junctions along a road, so that traffic may flow progressively along the road with a minimum of delay ('green wave' system). A further linked system links signals on a group of closely associated junctions to form a single traffic complex (5).

Grade Separated Junctions

Where ultimate traffic volumes to be handled at a junction are likely to exceed 5,000 vehicles per hour, then grade separation of the major traffic streams will be necessary. One of the most usual methods is to carry the main traffic flows over or under a surface level roundabout. This method has the great advantage that the roundabout can be constructed first, followed later by a fly-over when the traffic has increased, and its land requirements are not excessive.

With larger flows, grade separated junctions will probably be introduced, where traffic streams receive a greater degree of separation but some weaving of lighter traffic is permitted. At the other end of the scale, we have the fully directional no-weaving type of junction, often of the clover-leaf pattern, where no traffic is restricted; but these require vast areas of land and are extremely costly to construct, possibly of the order of £700,000 to £1 million each. A typical flow diagram for a grade separation scheme is illustrated in the Ministry of Transport Memorandum (5).

A grade separated intersection of a motorway (M2) and a class A road (A228) is illustrated in Plate VIII. The prestressed concrete overbridge with open balustrades clears the motorway in a single elegant span. This plate also illustrates slip roads, road markings and road signs.

TRAFFIC SURVEYS

Traffic surveys are needed to determine the volume, origin and destination of traffic flows, prior to the design of road networks and intersections. Due allowance must be made for foreseeable increases in the number of vehicles when interpreting the results of traffic surveys.

There are five principal methods available for obtaining information on the origins and destinations of existing vehicles, as described in Government publications (1) and (5), and these are listed below:

(1) Roadside Interview

Vehicles are stopped at a number of points and the drivers questioned about their journeys. The answers are normally recorded on pre-printed forms and police assistance for regulation of traffic is advisable.

The numbers of personnel required can be reduced considerably by dealing with different survey points and different directions of travel on different days. It is desirable to take a sample only of vehicles passing the interview point to prevent queueing. An enumerator provides a classified count of all vehicles passing while interviews are proceeding.

(2) Postcards

Each driver is asked to complete and return a prepaid postcard given to him as he passes one of the selected points. The main weakness of this system is that a considerable proportion of the cards are not returned.

(3) Registration Numbers

In this method observers at various selected points record the registration numbers and classifications of vehicles entering and leaving the area. The results are analysed by comparing the lists of registration numbers of vehicles entering the area with those leaving it. It is customary also to record entry and exit times, as this assists in the matching of records and the calculation of journey times. It is desirable to stagger the observations at entry and exit points to allow for travel time through the area.

This method avoids delays to traffic but requires a large number of observers, some mistakes occur in the recording of registration numbers and a proportion of the vehicles 'get lost'.

(4) Tags on Vehicles

Coded tags are attached to vehicles as they enter the area and are removed as they leave it, and times of entry and exit are often entered on the tags. This is a relatively simple method to operate, although objections are raised by some drivers, who may remove the tags.

(5) Home Interviews

A sample of about 1 to 10 per cent of the population is interviewed at home, when information is obtained on the journeys made during the previous few days by all members of the household. It is a costly method and requires considerable organisation and the services of trained inter-

viewers. It seems advisable to make two visits to each house—at the first visit basic information is collected and forms for recording of journeys are left at the house, and the completed forms are collected on the second visit. One interviewer can normally deal with about 50 households per week.

Another alternative to this method is to send the forms by post with a letter and a prepaid envelope for its return.

Operation of Surveys

A great deal of information on the operation and analysis of the results of traffic surveys has been produced by the Road Research Laboratory and the Ministry of Transport (1) and (5).

The requirements of Ministry of Transport censuses are 16 operational hours (6 a.m. to 10 p.m.), but it is customary for practical reasons to reduce the period for traffic surveys to 12 or 14 hours, and to apply expansion factors to convert the results to the 16-hour standard. Similar traffic patterns are generally encountered on Monday to Friday, but at Halifax the survey was carried out on Tuesday and Wednesday, as a result of information collected from automatic traffic counters (11). At Halifax a briefing session preceded the actual survey and articles were published in the local press a few days earlier, stating the purpose of the survey and asking for drivers' co-operation. It was found that one interviewer could conduct 100 to 150 interviews per hour and the average interviewing rate for the complete survey was 79 per man per hour. The Halifax survey was carried out on the basis of alternate 2-hour shifts.

When carrying out a traffic survey in a town it is usual to break the town down into a series of zones, which are the catchment areas of main roads—at Halifax the area of the borough was covered by 16 such zones and a further 15 external zones were established around the principal traffic routes entering the town. Census points were established on all important traffic routes near the boundary of the central area of the borough.

The data collected in a traffic survey is so extensive that it makes mechanical analysis essential. Coding of survey sheets and processing by the punched card system is frequently adopted.

Traffic Assignment

To assess the efficiency of a proposed road system and to determine the number of lanes and types of intersection, the distribution of future traffic movements must be known. Journey time is the most commonly

used factor for traffic assignment, and it can be safely assumed that the majority of vehicles will travel by routes which reduce this to a minimum. Journey times can be determined by driving a test car with an observer along existing routes and estimating the times for proposed routes.

Graphical methods can be employed to find the quickest routes and electronic digital computers have been used for processing large amounts of data on some traffic assignments.

TRAFFIC CONTROL

It is necessary to restrict the movement of vehicles, particularly in the larger urban areas, in order to secure the orderly and safe movement of traffic and the maximum use of our roads. This aspect has been highlighted in the Buchanan Report (2), which recommends that the two general aims for cities in the motor age should be to provide for the efficient movement of traffic and at the same time maintain good living conditions in the adjoining areas. It is suggested that in the larger cities, these conditions may only be capable of achievement by redeveloping on two or three separate levels. It is felt that in the long run it will be necessary to impose a 'ceiling' on private car traffic in busy areas and to increase the provision of good, cheap public transport.

Municipal engineers are actively concerned with the implementation of traffic control measures designed to secure the best use of the existing street network by preventing through traffic from using local streets, to increase road safety, to operate automatic traffic control devices so as to obtain maximum traffic flows, to improve loading and parking facilities and to provide a good public transport service.

Traffic Signals

As described earlier in this chapter, traffic signals have an important part to play in the operation of road intersections in urban areas. It seems almost inevitable that large city traffic networks will eventually have to be co-ordinated and controlled from a central control point, either by closed-circuit television cameras and detectors or a computer control system.

Traffic Signs and Street Markings

Traffic signs and markings on the road surface, usually in plastic, provide basic aids to traffic movement and safety. Lane markings, for instance, separate and discipline traffic so that maximum possible

capacity coupled with safety is achieved. Reference should perhaps be made to the use of double white lines, where vehicles are prohibited from stopping and must keep to the left of the continuous line where it lies on the left of a broken line or a continuous line.

Signs and markings are used on a large scale for control of road intersections, such as a 'Stop' sign in conjunction with a continuous double white line across the road and the word 'stop' painted on the carriageway surface, where sight line visibility is severely restricted; and 'Give way' signs in conjunction with a broken double white line across the road and a 'Give way' arrow, 12 ft by 4 ft overall, on the carriageway surface.

There are a number of prohibitory traffic signs, whose purpose is to instruct drivers as to what they must not do. Such signs include 'No right turn', 'No left turn', 'No U turns', 'No entry', (mainly associated with 'one-way' streets), 'Playstreet' (all vehicles prohibited), 'No motor vehicles, except for access', 'No buses and coaches', 'Restrictions on lorry access', 'No riding of cycles or mopeds' and 'No overtaking'. Most signs must have either reflective or electric illumination, but certain ancillary signs need not be illuminated when sited within 50 yd of an electric street lamp (12).

The main characteristics of traffic signs can be grouped according to the functions of the signs. For instance, warning signs such as 'cross roads' and 'roundabouts', are triangular in shape with a red border, white ground and black legend.

Regulatory signs of a prohibitive nature, such as 'no right turn' or 'maximum speed limit', are circular in shape with a red border, white ground and black or black/red legend; except waiting restriction signs, which have a red border, blue ground and red legend. Directional signs, such as 'turn left', are circular in shape with a white border, blue ground and white legend.

Directional informatory signs are all rectangular in shape but they vary in their colouring according to the class of road served. Primary route signs have a white border, green ground and white/yellow legend. Other route signs have a black border, white ground and black legend, while motorway signs have a white border, blue ground and white legend.

Waiting and Loading Restrictions

It is imperative that internal traffic should be permitted to move freely around the central business area of a town or city. To make this effective, a rigid enforcement of 'no waiting' restrictions and prohibition of loading

and unloading is necessary at peak periods. Waiting restrictions are indicated by yellow lines in the channel and loading and unloading restrictions by yellow lines across the kerb.

Coupled with waiting restrictions is the need for well-sited car parks of adequate capacity. This aspect will be dealt with in more detail later in this chapter.

Promotion of Public Transport

It seems evident that private motorists will have to be discouraged from traversing city centres and some degree of prohibition may eventually have to be imposed. This is particularly the case in some of the older and more historic cities, such as Norwich, where the environment would be ruined if it had to be adapted to cope with future traffic needs in their entirety (2). The road safety aspect also has an important bearing on these factors (13).

Provision for the greater use of public transport is being made in the more recent plans for the redevelopment of city centres. In some cases public transport will be permitted to penetrate deeper into the heart of the replanned city than private cars and in other cases, notably Leicester, new and novel forms of public transportation are being considered.

Public transport gains from the economies of scale resulting from the fuller use of vehicles, the use of larger vehicles and the advantages of large-scale organisation of transport facilities. Public transport costs per passenger mile are often less than those of the private car, as the average number of persons per private car is unlikely to exceed 1.5. The preference for use of cars, as against the use of public transport, is partly due to added convenience and partly due to irrational motives (14). Furthermore, the numbers of persons walking to work to avoid congested traffic conditions has probably increased considerably in recent years.

Basically, a much improved and extended public transport system will be needed in most urban centres, to convey vast numbers of persons into town centres for business, shopping and cultural purposes and to relieve the heavy congestion on urban traffic routes. Coupled with this development will be the increased provision of pedestrian shopping precincts and streets.

PARKING

Parking is one of the major problems in any large urban centre. To determine the extent of the problem, many local authorities undertake

surveys of parking duration, concentration and habits in their areas, and these are well illustrated in *Planning Bulletin No. 7* (20). Parking surveys in Glasgow have shown that 9,000 vehicles are parked on the streets with a saturation period between 11 a.m. and 3 p.m., but that 77 per cent of the cars parked were short-term parkers (2 hours or less). In London, there were 50,000 cars parked on the streets in the peak hour in 1959, and most of these stayed for periods longer than 2 hours (15).

Kerbside Parking

Parking is, however, prohibited in many urban streets and, others have limited waiting facilities, often of 30 minutes duration. These restrictions are sometimes enforced by traffic wardens, who have taken over certain traffic control functions under the direction of the police. In general traffic wardens have co-operated well with motorists, advising them where parking is an offence and directing them to more suitable parking areas. Another form of parking restriction for use in the narrower streets is that of 'unilateral parking', where vehicles are permitted to park for limited periods on opposite sides of the street on alternate days.

In general kerbside parking needs to be rigidly controlled and is best restricted to short-term parkers, who are mainly shoppers and clients, as distinct from those actually employed in the town centre. In Halifax, it was found from a survey that 77.2 per cent of vehicles parked at the kerbside in roads in the town centre stayed for not more than 20 minutes (11).

Parking Meters

Parking meters were first introduced into this country in July 1958, in Westminster. They have since been used extensively throughout the London area and in many provincial cities. The consent of the Ministry of Transport is needed and the local authority may have to prove that the provision of meters will permit free movement of traffic, allow reasonable access to premises and that full consideration has been given to the interests of owners and occupiers in the area. They frequently meet with opposition, are wasteful of road space and are aesthetically undesirable. On the other hand, they do provide a means of controlled parking where the motorist knows he can park and for what period, and has ample room to drive in and out of the parking space.

There are a number of different types of meter, single or twin, and mounted in a variety of ways. On aesthetic grounds they are best attached to walls, thereby eliminating the need for posts. Parking meters normally

operate on the 'excess charge' basis, allowing parking for an extended period for an excess charge. The majority of meters are of automatic operation upon insertion of the coin. They need testing for timekeeping every month and a complete overhaul every year (16).

Surface Car Parks

Surface car parks are quite efficient in operation and are favoured by the motorist. Cleared sites resulting from enemy action satisfied parking needs in the early post-war years, but most of these have since been required for redevelopment. *Planning Bulletin No. 7* shows how the appearance of surface car parks can be vastly improved by judicious tree planting (20). With the continually rising cost of land in the central areas of towns and the increasing number of vehicles, it is no longer practicable to satisfy all parking needs in large towns in this way, and additional storage space will have to be provided above or below ground.

Multi-storey Car Parks

The provision of large numbers of multi-storey parks in the larger towns in future years is essential to avoid excessive congestion of urban streets. They should, preferably, be sited near the main radials leading to the town centre, so that cars will not need to pass through the main shopping streets on entering or leaving the town. Furthermore, they should be located and designed so that they will not cause excessive congestion in adjoining streets during the rush hours. The constructional costs of multi-storey car parks may be justified where land values exceed £70,000 per acre, and the capacity of the park is not less than 200 cars. A five-storey ramped type car park occupying a one-acre site can accommodate about 850 cars, with parking spaces normally 16 ft × 8 ft (18).

It is interesting to note that a multi-storey car park constructed in Edinburgh, in 1962, has access by means of two continuous ramped spirals at a gradient of about 1 in 35. This method of design, which has since been used quite extensively in this country, eliminates internal loss of space due to ramps between floors, but there may be architectural problems where the sloping floors do not merge satisfactorily with the horizontal lines of adjacent buildings (17). The more usual design of multi-storey car park has horizontal floors connected by ramps, usually laid at a slope of about 1 in 10. The means of access and exit to car parks are frequently controlled by automatically operated barriers, the driver paying the parking fee into a machine beside the barrier without leaving his car. The cost of customer parked ramped type multi-storey parks not exceeding 5 storeys in height, exclusive of land, was in the order of £300

to £600 per car space in 1965. Plate IV illustrates a multi-storey car park at Bedford.

The multi-storey park illustrated has parking space for 569 vehicles on five floors, with shops and public conveniences on the ground floor. The main tower houses twin passenger lifts and there are also staircases between floors. The main structure is of reinforced concrete column and slab construction with 2 car spaces between each pair of columns and 7 in. floor slabs without beams. There is a clear height of 7 ft 5 in. and the floors at front and rear are staggered giving a change of level of 4 ft, and the floors are connected by internal ramps at a gradient of 1 in 8.

Electric lighting is provided by fluorescent fittings on each floor and ramp. The front and rear elevations of the building are open and fitted with aluminium safety balustrading with Georgian wired glass panels, protected from vehicular damage by rubber buffer stops in the floors. Constructional costs (1961 and 1963) amounted to £320 per car space.

In some areas, notably Coventry, roof top parking has been adopted to advantage. Its practicability depends upon the height of buildings, area of roofs available and the extent to which bridging is possible between the roofs. At Coventry, the parking spaces are provided on the roofs of the buildings in the shopping centre, which are connected by bridges to open deck car parks. The open access ramps are electrically heated to prevent ice formation.

Readers requiring further information on the layout of multi-storey car parks are referred to the paper by P. Marshall and G. P. Allen (21).

The costs of multi-storey car parks are now being reduced considerably by the use of industrialised system-built structures to standard layouts and dimensions.

Car Parking Needs

The Institution of Municipal Engineers estimated that there was an average deficiency of 7 'off-street' car spaces per 1,000 population in 1961 and that a further 14 spaces per 1,000 population would be needed by 1971 (19). This gives an indication of the vast number of additional parking spaces which will have to be provided in the coming years, mainly by local authorities, who have a direct responsibility for meeting the cost of public car parking.

In addition, local planning authorities should prescribe and enforce car parking conditions, when granting planning consent for commercial and industrial buildings. A commonly accepted requirement is one car space for every 500 ft² of new shopping, office, warehouse or factory

building. Difficulties in implementing this condition have arisen on occasions due to site conditions and the owners may also place undesirable restrictions on the use of the parking spaces (19). A useful paper on the assessment of parking needs and design of multi-storey parks is given in reference 22, at the end of this chapter.

LANDSCAPES

Trees and shrubs can advantageously be planted beside roads to serve a variety of functions. These functions include protection from strong winds, noise absorption, screening, prevention of soil erosion on steep slopes, formation of crash barriers, reduction of headlight glare, forming highway boundaries, reduction of monotony and providing interest.

Care must be taken to select suitable trees having regard to soil, climate, degree of exposure, space available and position of services. Large trees which have been used successfully on road planting schemes, where adequate space is available, include ash, beech, hornbeam, horse chestnut, lime, maple, Turkey oak, Scots pine and sycamore. Lombardy poplars can be very effective, but do not flourish in clay soils and must be kept well away from buildings and drains. Suitable smaller trees of the flowering variety include almond, cherry, crab and mountain ash (rowan). Popular shrubs include berberis thunbergii, berberis darwinii, cotoneaster henryana and forsythia spectabilis.

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CHAPTER TEN

Town and Country Planning

TOWN and country planning is necessary to ensure that all development is co-ordinated with an eye to the future, and carried out in such a way that it will assist in producing a community environment that will advance human welfare in health, well-being and safety. The best results in planning will be achieved by effective teamwork on the part of the professions involved, which include municipal engineers, architects and surveyors as well as geographers, economists, sociologists, etc. The skills required are so diverse that no one individual or profession could possibly possess them all.

THE NEED FOR TOWN PLANNING

Town planning has been defined as 'the science and art of shaping and guiding the physical growth of communities, in harmony with social and economic needs'. There is little doubt that in the absence of effective planning, development is likely to be haphazard and disjointed, without regard for planning principles or the putting of land to its best use in the interests of the community. Many defects are apt to arise from unplanned development; such as waste, congestion, disharmony, undesirable mixing of incompatible uses, lack of social services and unnecessary loss of good quality agricultural land.

In planning, we are directly concerned with the requirements of various land uses, their distribution and the relationship between them. It is important to realise that in controlling land use, the planner is also controlling people.

The need for planning at all levels (national, regional and local) has become more generally recognised in recent years, largely due to the

rapidly increasing population and amount of road traffic, and the urgent need for vast schemes of urban renewal. Skilfully prepared and imaginative plans are essential if these great problems are to be settled satisfactorily.

Plans must be forward-looking to provide for changing patterns and conditions. An estimated increase in the population of England and Wales of over 7 million, between 1961 and 1981, a reduction in the average size of households, resulting in more dwellings being required for the same number of people, changing patterns of employment, new forms of transport, new leisure activities and the doubling of the number of private cars between 1960 and 1970, all need to be catered for in town plans.

National Planning

A greater emphasis is now being placed on the need for planning at national level. The setting up of a Ministry of Land and Natural Resources in 1964, responsible for the availability of natural resources to meet the needs of the community, the development of new natural resources and the better use of existing resources, is one example of initiative taken at national level. Considerable guidance on planning matters is given to local planning authorities and local authorities generally by Government departments, in particular the issue of planning bulletins has proved very useful. In the wider field, national plans are needed for transportation, location of industry and population and other major aspects.

Regional Planning

The areas covered by local planning authorities are not always sufficiently extensive when dealing with some planning matters. For instance, a unified approach is needed when dealing with a county borough and the surrounding 'urban field', in which rural areas are subject to considerable urban influence. Yet planning powers are given to two separate planning authorities—the county borough council and the county council. Hence, there is a real need for some measure of regional planning.

In 1965 the Government set up a number of regional economic planning councils and boards, to provide effective machinery for regional economic planning within the framework of the national plan for economic development. The main functions of regional economic planning were stated to be:

- (1) To provide for a full and balanced development of the country's economic and social resources.
- (2) To ensure that the regional implications of growth are clearly understood and taken into account in the planning of land use, of development, particularly industrial development, and of services.

The economic planning councils are concerned with broad strategy on regional development and the best use of the region's resources, mainly by assisting with the formulation of regional plans and advising on their implementation. They have no executive powers.

The economic planning boards provide the necessary machinery for co-ordinating the work of Government Departments concerned with regional planning and development.

In addition, comprehensive regional studies have been made covering the greater part of the country, and these were actively concerned with the problems and needs of the areas reviewed and helped to indicate how the increasing population and overspill can best be accommodated.

Town Planning

Town planning aims at providing properly sited land of the correct amounts and of suitable physical characteristics for a variety of different uses. In all cases allowance must be made for possible future increases in population and for development in suitable stages. The road proposals must form an important element of a town plan and due attention must be paid to three-dimensional aspects. The aim must be to produce towns in which it is safe, convenient, healthy and pleasant to live and work.

Rural Planning

The needs of the countryside must not be overlooked. Tremendous harm was caused to the countryside by uncontrolled development between the two great wars—urban sprawl into rural areas, often in the form of ribbon development, sporadic and undesirable building throughout the countryside and development, such as the unrestricted display of advertisements, which gravely injured amenities. Planning aims at concentrating rural building into compact villages, which have the economic strength to support the shops, entertainments and public services, which the public need. Furthermore, great care is needed over detailed siting and design, to ensure that the new development can be absorbed by the village without losing its distinctive character.

The reduction in the demand for rural workers, due to greater mechanisation of farming operations, has been more than offset by the

increasing demand for rural houses by townsmen, who travel daily to work in the towns and cities. This process has been accelerated by the increased use of private cars, improved public transport and the increased provision of piped water, mains electricity and main drainage in villages. There are, in fact, few rural areas in the lowlands of England, excluding the area around the Wash, which are more than 20 miles from a town of 50,000 population or over.

PLANNING CONTROL

Planning Authorities

The local planning authorities, responsible for the exercise of planning powers under the Town and Country Planning Act, 1962, are the councils of county boroughs and counties. A joint planning board may be established to administer an area lying within two or more counties or county boroughs, if the Minister of Housing and Local Government considers it expedient. County councils may delegate planning control functions to borough and district councils under delegation agreements. The detailed delegation arrangements vary from county to county, but in general the borough or district council acts as agent of the county council (the local planning authority) and issues decisions upon planning proposals submitted to it, in accordance with the delegation agreement. A council of a county district with a population of 60,000 or more can claim, as of right, a wide measure of delegation of planning powers.

The planning decisions are usually based upon recommendations made by the district council's officers together with those submitted by the county's area planning officer. In some cases, the county district council has a substantial measure of independence to give decisions on certain types of proposal in accordance with county council policy, while in other cases the district council is nothing more than a 'postbox' for the county council.

Permission for Development

Planning applications have to be submitted through the local authority for planning permission in respect of most forms of development, in addition to whatever other consents may be needed under building regulations, Highways Act, etc. 'Development' is defined in the Town and Country Planning Act as 'the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in the use of any buildings or other land'.

There are a number of operations and uses of land which, by virtue of the Act (Sec. 12), do not constitute 'development', and an application for planning permission is not required. These exceptions are:

- (1) The carrying out of any works for the maintenance, improvement or alteration of a building, which affect only the interior or do not materially affect the external appearance of the building.
- (2) The use of any building or other land within the curtilage of a dwelling house for any purpose incidental to the enjoyment of the dwelling house, such as the use of an existing outbuilding as a hobbies room or children's playroom and all normal gardening activities.
- (3) The use of any land and the buildings on it for the purposes of agriculture or forestry.
- (4) The change of use of a building to another use within the same class, as listed in the Town and Country Planning (Use Classes) Order, 1963, which prescribes 18 separate classes of buildings.
- (5) Roadworks by a local highway authority.
- (6) The maintenance of sewers, pipes, mains, cables, etc. by a local authority or statutory undertaker.

It is expressly stated in the Act that the following do constitute a material change of use and therefore require planning permission:

- (1) The use as two or more separate dwellings of a building previously used as a single dwelling.
- (2) The deposit of refuse or waste material, unless the land is already so used and the area of the deposit is not extended and its height is not extended above that of the adjoining land.
- (3) The display of advertisements on part of the exterior of a building not normally used for this purpose.

Permitted Development

Furthermore, there are a number of operations listed in the Town and Country Planning General Development Order, 1963, which are permitted without the need to obtain planning permission, and these are known as 'permitted development'. The principal items of permitted development are:

- (1) Development within the curtilage of a dwelling house, including the enlargement, improvement and alteration of the house provided:
 - (a) It does not exceed 1,750 ft³ or $\frac{1}{10}$ of the cubic content of the house (whichever is the greater).

- (b) It does not project beyond the forwardmost part of the original building.
- (c) The height does not exceed the height of the original dwelling. This exemption is designed to cover the majority of domestic garages, extra rooms, porches, bay windows, etc.
- (2) The construction of gates, fences and walls provided they do not:
 - (a) Exceed 4 ft in height where they abut a highway.
 - (b) Exceed 7 ft in any other case.
- (3) The painting of the exterior of buildings other than for advertisements.
- (4) Permitted changes of use of buildings from:
 - (a) General industrial building to use as a light industrial building.
 - (b) One kind of shop to another, except that changes to the following need permission:
 - (i) Fried fish shop.
 - (ii) Tripe shop.
 - (iii) Shop for sale of pet animals or birds.
 - (iv) Cat's meat shop.
 - (v) Shop for sale of motor vehicles.
- (5) The erection of a temporary building on land for which planning permission has been given for operations, other than mining, for the duration of those operations. This refers particularly to contractors' site offices, stores, etc.

The General Development Order also covers the use of land for a period of 28 days; uses by recreational organisations; forestry buildings and works; development for industrial purposes; repairs to unadopted streets and private ways; repairs to services; war damaged buildings, works and plant; development under local or private acts or orders; development by local authorities, rivers boards, sewerage authorities, statutory undertakers, mineral undertakers, National Coal Board and that previously sanctioned by a Government Department; use of aerodrome buildings; use as a caravan site and development on licensed caravan sites.

Planning Applications

Planning applications are submitted on standard printed forms, issued by the local planning authority and obtained from that authority or the local authority (e.g. the district council). The forms are generally required to be submitted in triplicate to the local authority, except where the development adjoins a trunk road, when four copies are usually needed. The application must give all the particulars required by the

application form, and be accompanied by a plan, sufficient to identify the land, and such other drawings as may be needed to describe the development.

In order to safeguard the interests of all owners and some agricultural tenants of land and/or buildings, each planning application must be accompanied by a certificate stating that:

- (1) The applicant is the owner in fee simple, or entitled to a tenancy of the land to which the application relates; or
- (2) The applicant has given the requisite notice to all persons, who 21 days before the date of the application were owners of the land which is the subject of the application.
- (3) The applicant is unable to trace all or some of the owners of the land to which the application relates, and has served the appropriate notice on those he can trace, and in respect of the unknown owner(s) has published in a local newspaper a requisite notice of the application.

In all cases other than when the applicant is the owner or tenant of the land, the local planning authority cannot determine the application before 21 days after the date of the latest service of notice.

Where the application relates to industrial buildings exceeding 5,000 ft² or 1,000 ft² in London, the Midlands and S.E. and E. England, or office buildings in excess of 3,000 ft² in the metropolitan region and certain other areas, these must be accompanied by an industrial development certificate or an office development permit issued by the Board of Trade, before they can be considered by the local planning authority (see the Control of Office and Industrial Development Act, 1965). This procedure has been introduced to ensure a proper distribution of factories and offices on a national scale—the priorities being to encourage new industrial building in development areas and to channel new office building away from the London area.

Certain types of application must be advertised to enable interested persons to make representations to the local planning authority. These applications include public conveniences, sites for the disposal of refuse or waste materials, sewage disposal works, slaughter houses, knackers' yards, theatres, cinemas, music-halls and dance-halls.

A prospective developer often wishes to know whether the development he has in mind is likely to receive planning permission, before he purchases the land or incurs the cost of preparation of detailed plans. In these circumstances, the developer is able to submit an 'outline application', which entails merely the submission of an application form and a site plan. Consent may be given subject to subsequent approval by the

local planning authority of any matters relating to siting, design and external appearance of the buildings. In this way, the applicant can obtain officially the local planning authority's reaction to his proposals, without the necessity of preparing full plans and drawings of the scheme.

Planning Decisions

All applications are duly acknowledged and the details recorded in a planning register, which is available for inspection by the public. The entries in the register will include details of the applicant and agent (if any), nature and location of development, decision and result of appeal (where applicable).

A local planning authority can deal with an application in one of three ways:

- (1) Grant permission unconditionally.
- (2) Grant permission subject to conditions.
- (3) Refuse permission.

The decision must be given to the applicant in writing within 2 months of the date of receipt of the application, or 3 months where a trunk road is involved. Decisions must include reasons for refusal or for any conditions attached to a permission.

When determining an application, a local planning authority must have regard to the provisions of the development plan and any other material considerations. Examples of 'other material considerations' listed by the Ministry of Housing and Local Government are 'the effect of the proposed development on the safety of traffic or on the appearance of the surroundings; the effect on public services like main drainage, water supply or schools; the possibility that the land concerned might be needed for some important public purpose, such as the widening of a road or the erection of a new school; the need to ensure that the best use is made of scarce land and the need to ensure that valuable minerals are not made inaccessible by the erection of buildings over them' (see reference 1 at the end of this chapter).

If an applicant is aggrieved by the decision of the local planning authority, he may appeal to the Minister of Housing and Local Government, on a form obtainable from the Ministry. Notice of appeal is to be given within one month of the date of the decision.

Planning Appeals

Many appeals are dealt with by the speedier 'written representation' procedure, in which both parties submit written statements to the Minister of Housing and Local Government. Each party receives a copy of the

statement made by the other and can make written comments on any of the points made. A Ministry inspector will visit the site and report to the Minister, who will subsequently determine the appeal, giving reasons for his decision. Valuable information on past planning appeals can be obtained from selected appeals issued by the Ministry (2).

Local inquiries, before a Ministry inspector, are often held in connection with the more important planning appeals. The procedure at these inquiries is similar to that in a Court of Law, but is rather more flexible and informal. For instance, there is some relaxation of the rules of evidence, and it is customary for witnesses to read their evidence, after circulating copies to the inspector and the opposing party. The procedure at a local inquiry is generally as follows:

- (1) The appellant or his representative makes an opening statement outlining his case.
- (2) The appellant calls witnesses to give evidence and these are cross-examined by the local planning authority's representatives and re-examined, if necessary, by the appellant. The inspector may also ask any questions that he wishes.
- (3) The local planning authority's representative makes an opening statement and calls his witnesses in the same manner as the appellant.
- (4) The local planning authority's representative can make a closing statement if he wishes.
- (5) The appellant or his representative makes a closing statement.
- (6) Any other interested parties are invited to make statements and are often cross-examined.
- (7) The inspector visits the site accompanied by a representative of each party, who can identify objects mentioned at the inquiry.

As with written representations, the inspector prepares a report for submission to the Minister. The Minister subsequently communicates his decision in writing to the parties, with his reasons.

Readers requiring further information on planning appeals or inquiries are referred to the book by A. E. Telling and F. H. B. Layfield (3).

Enforcement of Planning Control

The Town and Country Planning Act and supporting regulations, etc. provide the machinery for the prevention and restoration of planning contraventions. In the majority of cases where development is carried out without planning permission it is work of a minor nature, where the developer was unaware of the need to obtain planning consent, and

when the irregularity is pointed out to him he is usually quite happy to submit an application. Notice of undesirable development often reaches the local planning authority through members of the public.

Enforcement action must be taken by the local planning authority within four years of the development being carried out, by the service of an 'enforcement notice' on the owner or occupier of the land. After this period the local planning authority will have to pay compensation, where remedial works are required, hence the authority needs to keep a watchful eye for any unauthorised development.

Purchase Notices

Where the local planning authority or the Minister refuse permission for the development of land or grant permission subject to conditions, an aggrieved applicant who is also the owner, may, in certain circumstances, require the local authority to purchase his interest in the land. This takes the form of a 'purchase notice' served within 6 months of the planning decision, which requires confirmation by the Minister before it can become effective.

Before confirming a 'purchase notice' the Minister must be satisfied:

- (1) That the land has become incapable of reasonably beneficial use in its existing state.
- (2) Where permission has been granted subject to conditions, that the land cannot be rendered capable of reasonably beneficial use if the development is undertaken in accordance with these conditions.
- (3) In any case, that the land cannot be rendered capable of reasonably beneficial use by the carrying out of any other development for which permission has been or will be granted.

Readers requiring a more comprehensive knowledge of planning law are referred to the book by Desmond Heap (4). A handy résumé of the law is given also in the book by J. J. Clarke (5).

Land Commission Act

At the time of completing this book the Land Commission Bill was in its final stages, with the following objectives:

- (1) To acquire land for the community where desirable.
- (2) To recover a part of the development value realised in land transactions.
- (3) To make more land available for development.
- (4) To reduce the market price of development land, particularly land intended for housing.

For these purposes vendors, lessors and developers will be liable to pay betterment levy after the appointed day on sales, new tenancies, start of development, receipt of compensation for revocation or variation of planning powers or the grant of an easement. The levy will probably be 40 per cent initially rising to 45 and 50 per cent, and will be charged on the difference between existing use value plus 10 per cent or last transaction price (whichever is the higher) and the market value.

DEVELOPMENT PLANS

Procedure

Local planning authorities are required to prepare development plans illustrating the major planning proposals for their areas. These plans must be reviewed by the local planning authority carrying out a survey, at least once in every five years. In this way the proposals are never really finalised as the plan is subject to constant review, to take account of changing conditions and to incorporate the latest concepts of good planning. Development plans and subsequent reviews have to be approved by the Minister of Housing and Local Government, and the proposals have to be duly advertised in accordance with the procedure detailed in the Town and Country Planning (Development Plans) Regulations.

Contents

A development plan shows:

- (1) The manner in which the land covered by the plan is to be used.
- (2) The stages by which the development is to be carried out.

A development plan may:

- (1) Define the sites of proposed roads, public and other buildings and works, airfields, parks, pleasure grounds and other open spaces. Areas which are defined are required specifically for the purposes indicated in the plan—for instance, an area scheduled for a school is required exclusively for that purpose.
- (2) Allocate areas of land for use for agricultural, residential, industrial or other purposes. Primary allocations shown on a Town Map include a number of subsidiary uses which are appropriate to the primary allocation. For instance, a residential area can include groups of two or three shops.
- (3) Designate certain land as subject to compulsory acquisition by a

Minister, local authority or statutory undertakers, as necessary to their functions.

- (4) Designate as land subject to compulsory acquisition by the appropriate local authority:
 - (i) Any land contained in an area defined as an 'area of comprehensive development', or any land contiguous or adjacent to it.
 - (ii) Any other land which, in the opinion of the local planning authority, ought to be subject to compulsory acquisition for the purpose of securing its use in the manner proposed by the plan.

Areas of Comprehensive Development

An 'area of comprehensive development' is defined in the Town and Country Planning Act, 1962, as an area which needs to be redeveloped as a whole:

- (1) For the purpose of dealing satisfactorily with extensive war damage (blitzed land) or conditions of bad layout or obsolete development (blighted land), or
- (2) For the purpose of providing for the relocation of population or industry or the replacement of open space in the course of the development or redevelopment of any area (overspill), or
- (3) For any other purpose specified in the plan.

Maps

A development plan generally consists of a basic map (such as a county map to a scale of 1 in. to 1 mile) and a written statement, together with any other maps that may be necessary. The additional maps include town maps (6 in. to 1 mile), comprehensive development area maps (1/2500), designation maps (1/2500, showing land designated as subject to compulsory purchase), street authorisation maps (1/2500, showing major new roads and road widenings) and programme maps (in conjunction with county, town and comprehensive development area maps, showing the stages by which the development is to be carried out).

Planning Blight

Proposals in a development plan may cause depreciation in value of certain areas of land, and persons affected may be able to make a claim for compensation arising from 'planning blight'. 'Planning blight' may occur in six cases detailed in the Town and Country Planning Act, 1962 (Sec. 138). They are principally concerned with land liable to compulsory acquisition or highway works (4).

PLANNING SURVEYS

Planning surveys are needed to collect the data upon which the development plan and other planning proposals will be based. They can be used to show the soundness of the proposals and will help councillors and members of the public to appreciate the principles involved and the need for the proposals.

The majority of planning surveys are presented in the form of maps, often worked up from a base map(s). Different land uses or other characteristics can be denoted by different colours, various forms of hatching, or edging and lettering. Detailed information on the method of execution of planning surveys can be found in *Surveys for Town and Country Planning* (6) and the Ministry Handbook on Central Areas (7).

A tremendous variety of planning surveys are undertaken and their subject-matter and scope vary considerably according to the type of area under review. A large number of surveys have been published, of which some of the most informative are the Greater London Plan (8), County of London Plan (9), Worcester (10), Manchester (11) and Herefordshire (12).

The principal types of planning survey are now listed:

Physical Features

Maps prepared under this category include:

- (1) Physical characteristics (contours, watercourses, etc.).
- (2) Physically difficult land (land which is excessively steep, liable to flood, excavated for mineral workings, etc.).
- (3) Agricultural characteristics (boundaries of farm units, agricultural quality of land, etc.).
- (4) Landscape factors (areas of scenic value, viewpoints, etc.).
- (5) Geological drift map (soil types).

'Sieve maps' are frequently used to assist in determining the suitability of land for development. Overlays indicating areas with different unsuitability characteristics are superimposed on one another, and land which has not been eliminated by the combined or sieve map may be regarded as suitable for development.

County Features

- (1) Spheres of influence or catchment areas of towns and villages, depending on the social services available.

- (2) Public utility services (routes, service areas and capacities of sewers, gas and water mains and electricity lines).
- (3) Communications and transport facilities (roads and bus and train routes with service frequencies).
- (4) Population (past and present densities).
- (5) Industry (location, type and numbers of employees).
- (6) Land use (forest and woodland, meadow land, arable land, heath-land, moorland, built-up areas, etc.).

Urban Features

- (1) Existing land use (residential, shopping, industrial, etc.).
- (2) Historical growth—periods often taken are pre-1875, 1875–1914, 1914–39 and post-1939.
- (3) Residential density (habitable rooms per acre).
- (4) Population density (persons per acre—usually considered excessive if it exceeds 1 person per habitable room).
- (5) Density of non-residential buildings, usually expressed in terms of 'floor space indices'.

The floor space index of a building =

$$\frac{\text{total amount of floor space of the building}}{\text{total area of building site} + \frac{1}{2} \text{ width of adjoining streets}}$$

Approximate guide figures for the different classes of buildings could be taken as:

Shopping area	1.5
Offices	2.0
Wholesale warehouses	2.25
Light industry	1.5

- (6) Public utility services, as previously described.
- (7) Roads showing traffic flows and accident danger spots (see Fig. 53).
- (8) Transportation—bus, coach, train, canal, air-routes, frequency of services, interchange points, etc.
- (9) Population—numbers, vital statistics, unemployment, family size, trends.
- (10) Industry—as previously described.
- (11) Housing—standards, life available, distribution, relation to family structure, etc.
- (12) Social services—schools, clubs, public houses, cinemas, theatres, health centres, clinics, museums, libraries, swimming baths, etc.
- (13) Shops—location, number and type.

- (14) Amenities—open spaces of all kinds—type, location, distribution, etc., and areas where amenities have been injured by bad development.

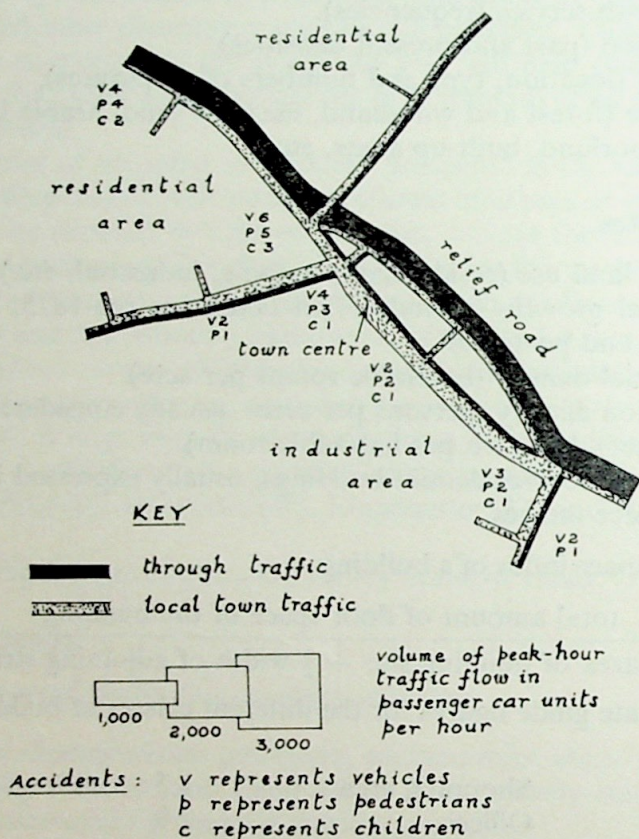


FIG. 53. Traffic flows.

PLANNING FOR VARIOUS USES

Main Business Area

The inner core of a town contains the main business area of shops, offices, and possibly some entertainment facilities and warehouses. In most towns this area is situated in one of the older parts of the town astride the main road intersections. The roads are often narrow and badly congested and replanning is urgently needed to provide safe and convenient shopping facilities with good transport arrangements.

It has been suggested that a suitable area would be about 100 acres for a town of 60,000 population, when planning new towns. It should,

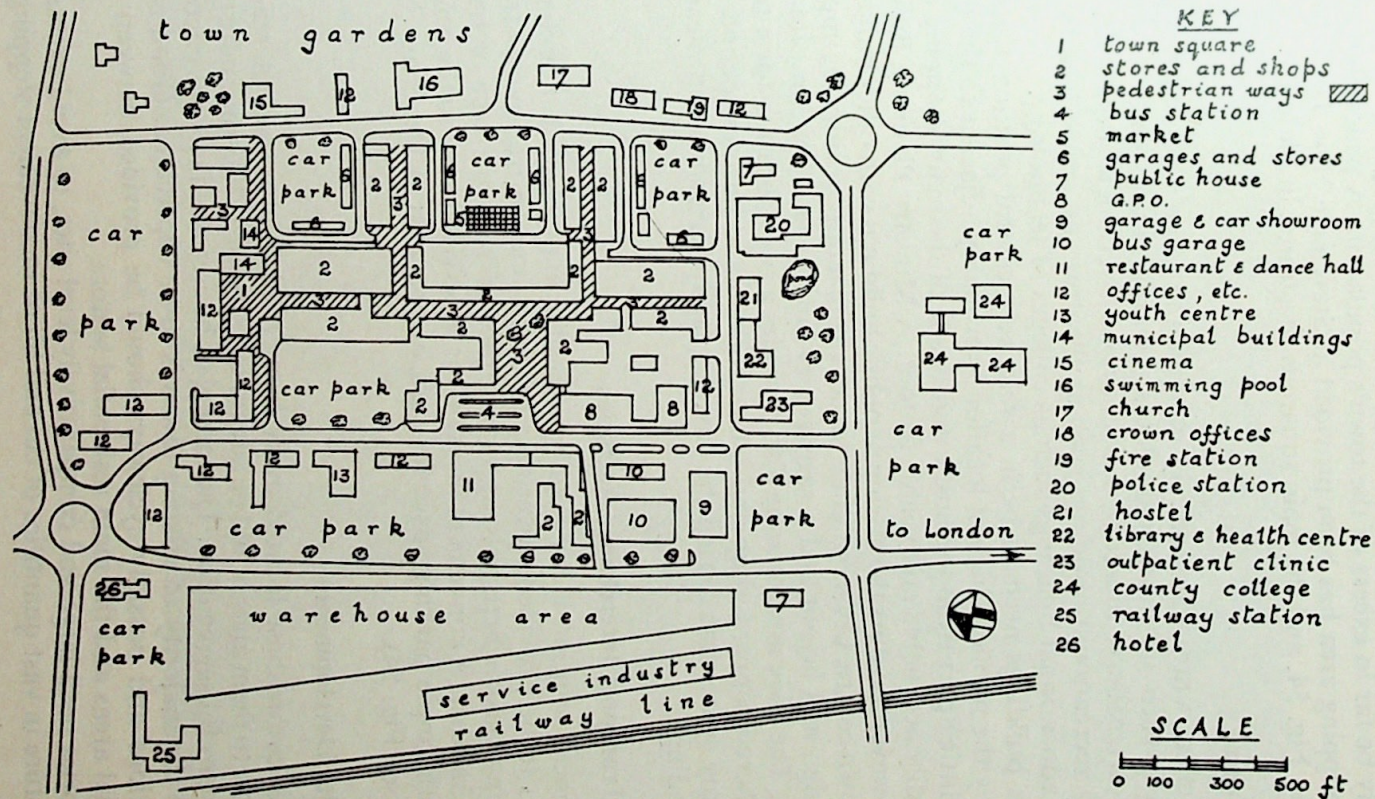


FIG. 54. Town Centre, Stevenage New Town.

however, be borne in mind that a town's shopping centre is likely to serve a considerable rural area, and so the shopping population will probably be far in excess of the town's population. A pedestrian-access main shopping area has been provided at Stevenage New Town and is shown in Fig. 54, and the main square is illustrated in Plate IX.

Civic Centre

The civic centre can usefully contain the town's principal public buildings, such as municipal offices, central police station, central library, art gallery, museum, law courts, Government buildings, and possibly recreational buildings such as theatres and concert halls, and further educational buildings such as colleges of technology.

These buildings need to be in a relatively central position for easy access by the public. The best location is probably adjacent to the inner core, a little apart from the hustle and bustle of the main shopping area but readily accessible and visible from it. A Ministry Planning Bulletin (24), however, favours the mixing of public buildings with other buildings in the town centre. Civic buildings present a great opportunity for impressive design and layout and a satisfactory landscape effect can often be created. The civic area or zone also provides a good location for a town park where shoppers, shop and office workers and business people can spend any spare time during the day, in readily accessible and pleasant surroundings.

Public Transport Interchange Facilities

The ideal solution is for readily accessible and grouped interchange facilities to be provided, covering all forms of public transport—train, coach and bus—where passengers can transfer from one type of transport to another. A convenient location for these is adjacent to the central area with ample parking space for cars, as provided at Stevenage New Town (see Fig. 54).

Industrial Development

Factories are best located away from residential areas but readily accessible to them and should be adequately screened. Noxious industries require careful segregation. The mixing of houses and factories encountered in the majority of existing towns is to be deprecated. Good road connections and possibly cycleways should be provided between the industrial areas and the main residential sectors.

Factories need large and comparatively level sites, to avoid excessive expenditure in vast quantities of cut and fill or inconvenient stepping of



IX Main Square, Stevenage New Town



X Upper Shopping Precinct, Coventry



XI Lower Shopping Precinct, Coventry

floor levels. All public services—water, electricity, gas, main drainage and telephone facilities—must be adequate. Good road transport is essential for bringing in raw materials and taking out the finished products. In some cases the availability of rail and water transport adjacent to the factory site can be a definite advantage.

Opinions differ as to whether the factories serving a new town should be located in a single area or industrial zone, as at Stevenage (13), or be distributed in several pockets—three were proposed at Hook (14). The ideal arrangement will be influenced by a number of factors, such as shape and size of town, topographical characteristics, capacity of public service networks, road network, etc.

The area of land required to accommodate industrial development varies a great deal with the type of industry. An allocation of 10 acres of industrial land per 1,000 population is a useful guide, based on $\frac{1}{4}$ of the population being industrial workers and an acre of industrial space being needed to accommodate 25 workers. The proportion of basic industrial workers in a town varies tremendously from about $\frac{1}{5}$ in dormitory areas to about $\frac{2}{5}$ in heavily industrialised towns. In addition there are non-basic or service industries such as business, commerce, transport, public services, building, etc., which serve the local needs of the population.

'Trading estates', wherein the land is in a single ownership and developed by the owner to offer special facilities to industrialists, can prove very useful. They may be financed by private enterprise (e.g. Trafford Park and Slough), sponsored by the Government to overcome depression in 'development areas' (e.g. Team Valley, Gateshead and Treforest, Cardiff) or laid out as industrial estates by the developing authorities in garden cities, new towns and expanding towns. In many cases the industrialist can select a design for his factory and have the factory erected on a rental basis.

Residential Areas

Residential areas need to be conveniently located in relation to work-places, shops, schools and other essential services. Sites for residential development should be physically suitable—not excessively steep, although some undulation gives character, above flood plains, reasonably healthy, etc. Adequate public services and good transport facilities are very desirable. The nature of adjoining development will also need to be considered.

The area of land required to house a certain number of people will depend on the overall residential density adopted. Garden cities and the earlier new towns adopted a net residential density of about 25 to 30

persons per acre (see Table 8 for a definition of 'net residential density'). In 1962, the Ministry of Housing and Local Government advised local authorities to adopt higher densities in residential areas, in order to reduce housing costs, conserve agricultural land and restrict urban peripheral growth (15). The Ministry advocates minimum net densities for local authority housing of 40 persons per acre, and points out that net densities of 60 persons per acre can be obtained with 2-storey houses and much higher densities still with 'mixed development' (flats and houses).

The following table extracted from the Dudley Report (16) gives suggested areas for various uses within 'neighbourhood units', together with suggested residential densities for neighbourhoods at varying distances from the centre of the town. The neighbourhood unit concept is described later in this chapter.

TABLE 8. LAND ALLOCATION FOR A RESIDENTIAL NEIGHBOURHOOD OF 10,000 PERSONS

<i>Use</i>	<i>Open develop- ment acres</i>	<i>Outer ring acres</i>	<i>Inner ring acres</i>	<i>Central acres</i>	<i>Central acres</i>
Housing	333	200	133	100	83
Primary schools (3-11 years of age) (including playing fields)	17	17	17	17	17
Open space	70	70	60	50	40
Shops, offices, etc.	9	8	7	6	5
Community centre, churches, etc.	7	5	4	3	3
Public buildings	4	3	2	2	2
Service industry and workshops	7	6	5	4	4
Main roads including half boundary roads, up to a maximum of 20 ft, and parking	35	28	20	17	14
TOTALS	482	337	248	199	168
Average net residential density* (persons per acre)	30	50	75	100	120
Gross neighbourhood density† (persons per acre)	21	30	40	50	60

* Net residential density is the average number of persons per acre of housing area; which comprises the curtilages of the dwellings, access or internal roads and half the boundary main roads up to a maximum of 20 ft, where these are contiguous to residential property.

† Gross density is the average number of persons per acre of the whole neighbourhood, the acreage of which is shown by the totals.

Social Services

An even distribution of social services throughout residential areas is necessary. These services include churches, public houses, cinemas, shops, schools, community centres, clinics, etc. The rate of distribution varies a great deal and it is made even more difficult by the variations which occur in the types and sizes of shops and schools. The following figures can at best only be used as a very rough guide:

<i>Social service</i>	<i>Approximate Population served by a Single Unit</i>
Church	2,000
Public house	2,000
Cinema	10,000/20,000
Shop	125
Secondary school	15,000 (1,110 pupils)
Primary school	2,500/5,000
Nursery school	1,700 (40 pupils)
Community centre	10,000
Clinic	10,000

A good case can be made out for grouping many of these facilities in neighbourhood centres, to form a social centre and focal point for the neighbourhood. Secondary schools often need to be located between two main residential areas, because of the larger population served by them. On the other hand, primary and nursery schools are best distributed evenly throughout residential areas, to reduce the length of journeys to and from school to a minimum.

School sites have a number of desirable requirements:

- (1) Reasonably level, regular-shaped, healthy site with pleasant surroundings.
- (2) Safe access away from traffic roads.
- (3) Freedom from noise.
- (4) Sufficient area to deal with future needs.
- (5) Ability to locate school buildings to provide an architectural feature.
- (6) Reasonably accessible from residential areas, with maximum walking distances of $\frac{1}{4}$ to $\frac{1}{2}$ mile for nursery school children, $\frac{1}{2}$ to $\frac{3}{4}$ mile for primary school-children and 1 to $1\frac{1}{4}$ miles for secondary school-children.

Open Spaces

The term 'open spaces' embraces both publicly and privately owned land used for a variety of purposes, such as sports grounds, golf courses, parks, cemeteries, allotments and stretches of open country of considerable amenity value. The late Sir George Pepler envisaged all the open spaces in a town being welded into an integrated open space system of radials and rings, whereby grassed and tree planted areas extended throughout the town. Basically, open spaces are free from buildings except sports pavilions and the like, and they provide fresh air, colour and shade in a town and help to take off some of the harshness of buildings and paved surfaces.

The area devoted to open space varies appreciably in different towns. An ideal overall figure is probably in the order of 10 acres of open space per 1,000 population. In most towns the areas allocated to open space are inadequate and badly distributed—the method of distribution often arising from chance rather than from positive planning.

Some open spaces, both public and private, provide facilities for sport and play, while others give rest and relaxation or bring amenity and fresh air into a built-up area. Some very large parks, such as Regent's Park, London, fulfil all these functions. Consideration will now be given to the main requirements of the various types of open space.

Parks

Parks are of three main types—national, regional and local.

National Parks are extensive areas of beautiful and relatively wild country, where the landscape beauty is preserved, access by the public maintained, wild life and interesting buildings protected and established farming use continued. Typical examples are the Lake District, Park District and North Wales. These constitute holiday centres for people from all parts of the country.

Regional Parks are similar to national parks but smaller; normally providing about 2 days walking and located within 30 to 40 miles of a large urban centre. Typical examples are Epping Forest and the North Downs.

Local Parks and Pleasure Gardens are provided in most towns and have high amenity value. They provide the means for day-to-day enjoyment of trees, grass, flowers, etc. and provision is sometimes made for boating and band concerts. Local parks are sometimes laid out on land which,

due to its physical characteristics, could not be otherwise usefully employed (e.g. the Bournemouth chimes). On occasions a local authority purchases a manor house and its grounds and makes them available for public use, as for instance the purchase of Newstead Abbey by Nottingham Corporation. The Greater London Plan recommended 1 acre per 1,000 population for parks and pleasure grounds.

Small Amenity Areas are often provided in the form of landscaped forecourts to single buildings or groups of buildings, such as civic buildings and groups of old persons' bungalows.

Playing Fields

Playing fields are required for both juveniles and adults, of which some need to be provided by local authorities for public use and others will be provided only for specific sectors of the community, e.g. school playing fields for school-children during school hours and private playing fields for use by club members.

The National Playing Fields Association has estimated that 6 acres per 1,000 population should be set aside as public playing fields and that private playing fields (excluding schools) should provide a further 3 acres per 1,000 population, on the basis of an average of 50 players per acre (9 acres per 1,000 population in all). The requirements for school playing fields are given in *Principles and Practice of Town and Country Planning* (17). There are certain essential site requirements for playing fields—readily drainable subsoil, above flood plain, reasonably level with slopes not exceeding 1 in 50 and of roughly rectangular shape for economic use.

Children's Playgrounds

Children's playgrounds laid out with playground equipment, should ideally be evenly distributed throughout housing areas at about $\frac{1}{2}$ mile apart and about $1\frac{1}{2}$ to 2 acres in extent. This gives an allocation of about $\frac{1}{3}$ acre per 1,000 population, but this is rarely achieved in practice. They are a most desirable feature in helping to keep young children from playing in the streets, with all the inherent dangers.

Cemeteries

The majority of cemeteries are located on the outskirts of towns with reasonable access from the centre. At present about 500 acres are used annually and one acre accommodates approximately 1,000 bodies.

The soil should preferably be dry and porous with the water table below the lowest grave level (10 ft below ground for treble depths).

Burial grounds are gradually being displaced by crematoria, which with their associated gardens of rest have not the unsightliness of cemeteries. A reasonable provision for crematoria would appear to be about 1 crematorium per 150,000 to 200,000 population.

Allotments

The demand for allotments varies tremendously according to the class of resident, size of private gardens and the distance of the allotments from the houses. The demand for allotments is the subject of a national investigation, and there is little doubt that there is widespread over-provision of this service due to a declining demand. A reasonable average provision would probably be in the order of $\frac{1}{2}$ acre per 1,000 population. Allotments need to occupy well drained good quality soil and be within $\frac{1}{2}$ mile of the housing areas they are planned to serve.

Allotments and their accompanying sheds frequently present a most untidy and unattractive appearance. Some local authorities have produced much improved layouts, with the use of boundary hedges and ornamental approaches (see Fig. 68).

PLANNING OF NEW DEVELOPMENT

The bulk of new development in this country, as distinct from redevelopment, is found in large areas of residential development and in new town and expanding town schemes. Post-war residential development has proceeded on vastly different lines to that carried out before the war.

Neighbourhood Units

One essential difference has been the frequent use of the 'neighbourhood unit' concept. A neighbourhood unit is a partially self-contained residential area of limited size, often accommodating about 5,000 to 10,000 persons. Each unit is generally separated from other units by parkways or other features, and each should preferably incorporate variations in layout, architectural treatment and in other ways, to give maximum variety and foster local interest.

The size of the neighbourhood has been determined by the population needed to justify the provision of various social services, such as community centre, clinic, shops, schools, churches, etc. The road pattern

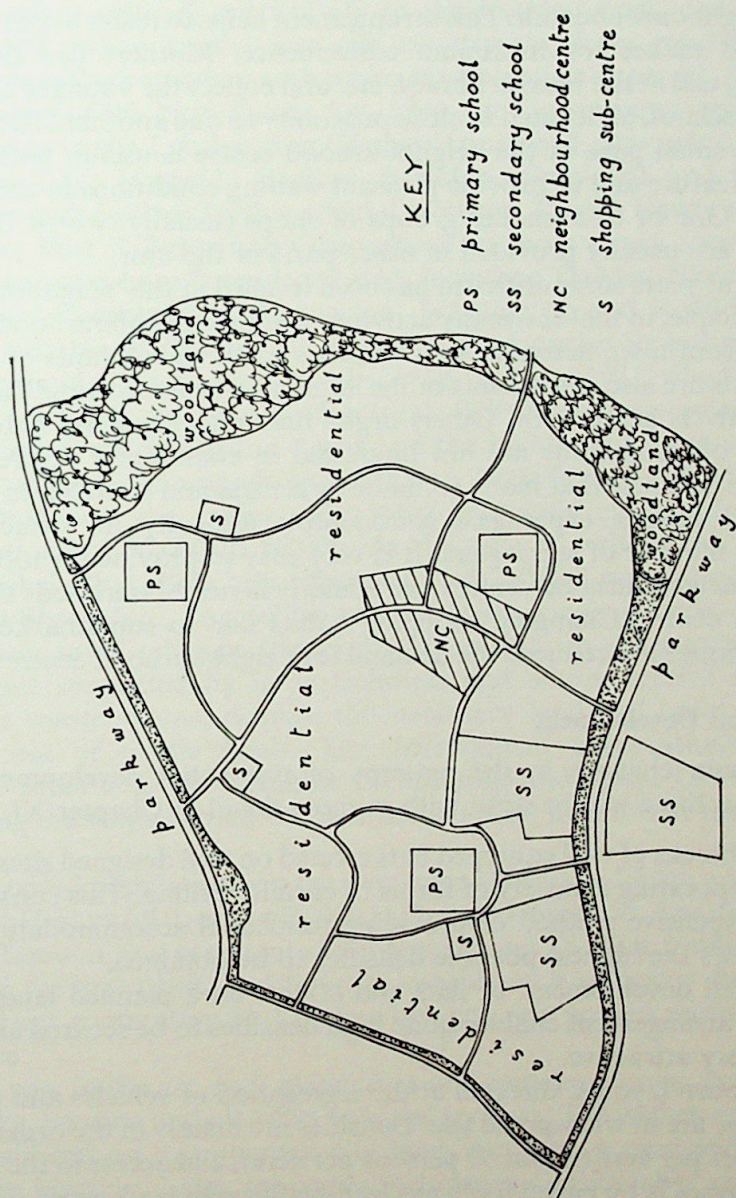


FIG. 55. Typical neighbourhood unit.

should be designed to discourage through traffic from entering the unit. The layout of a typical neighbourhood unit is illustrated in Fig. 55.

The majority of the service buildings should be grouped in the centre of the neighbourhood unit. This arrangement helps to foster a community spirit and makes for maximum convenience. Mothers can do their shopping, call at the branch library, etc. and collect the younger children from the school, all located in close proximity to one another. The provision of a small park at the neighbourhood centre is useful, both as an amenity feature and to provide pleasant waiting conditions in the better weather. One or two smaller groups of shops (usually two or three in number) are usually provided in other parts of the unit.

In recent years some criticism has been levelled at the 'neighbourhood unit' principle, in that too many activities within a neighbourhood divert interest from town activities as a whole, and the inhabitants of neighbourhoods are also inhabitants of the larger unit (the town) and they cannot effectively serve both. Others argue that with changing habits the majority of inhabitants are not interested in community centres, and there is little doubt that many community centres and churches in neighbourhood centres experience considerable difficulty in attracting a sufficient number of supporters. It is very easy to provide far too many shops in neighbourhood centres, particularly in neighbourhoods skirting the town centre. Changing shopping habits due to supermarkets and mobile shops have reduced the demand for neighbourhood centre shops.

Residential Development

The main changes in the patterns of residential development are listed, and these will be dealt with in more detail in Chapter XI.

- (1) Tall blocks of well equipped flats erected on well designed sites many incorporating a variety of forms of curtain walling. This constitutes an expensive method of providing residential accommodation but enables the highest possible densities to be obtained.
- (2) 'Mixed development' of flats and houses on a planned landscape. This arrangement enables quite high densities to be secured and can be very attractive.
- (3) Radburn layouts, directed at the segregation of vehicles and pedestrians, are in widespread use. Densities are mainly in the order of 16 houses per acre (about 50 persons per acre), and access to the fronts of houses is by paved footways leading through landscaped areas to shops and schools. Vehicular access is provided near the rear of houses with car parking space on the basis of one car space per dwelling.

New Towns

The continued increase in population and worsening congestion in the larger urban centres, particularly in the London area, coupled with continuing urban sprawl into the countryside, have resulted in the Government's proceeding with schemes of planned dispersal. Following the passing of the New Towns Act, 1946, the Government designated 8 new towns in the London ring (Hemel Hempstead, Stevenage, Welwyn Garden City, Hatfield, Harlow, Basildon, Bracknell and Crawley) together with 6 others further afield (Cwmbran, Corby, Newton Aycliffe, Peterlee, East Kilbride and Glenrothes). In more recent years further new town sites have been designated, including Dawley, Skelmersdale, Runcorn, Cumbernauld, Livingston, Washington and Redditch.

The South-east Study (18) estimated an increase in population in S.E. England of about $3\frac{1}{2}$ million between 1961 and 1981, which includes about 1 million net inward migration. The Study recommended the expansion of many existing towns and the building of three new cities with populations ranging from 150,000 to 250,000, as shown in Table 9. In comparison the earlier new town proposals envisaged ultimate populations of 50,000 to 60,000. At the time of writing this book, it seems likely that three new towns, each of 250,000 population, will be built in Shropshire, Lancashire and North Buckinghamshire.

In new town schemes the Government sets up development corporations supported by large technical and administrative staffs, to prepare master plans, acquire the necessary land and build the new towns out of public funds. The development corporations submit annual reports to the Minister of Housing and Local Government, detailing the work carried out and the financial position of the corporation.

The initial populations on the new town sites varied from a thousand or so at Harlow up to about 20,000 at Hemel Hempstead. The new towns in the London ring are situated between 25 and 35 miles from London, beyond the green belt, and this was considered a sufficient distance to discourage commuting to London but has not proved entirely so in practice.

The new towns are each planned as self-contained units, comprising industry, housing and all other essential services. The earlier new towns were laid out on open garden city lines, but with a predominance of terraced housing. Later proposals included a considerable amount of high density residential development around the town centres.

The earlier new towns were planned on the basis of a number of neighbourhood units. For instance, Stevenage, which is illustrated in

TABLE 9. AREAS SUGGESTED FOR EXPANSION IN SOUTH-EAST STUDY

	<i>Population 1961 (1)</i>	<i>Estimated natural change 1961-81 (2)</i>	<i>Possible scale of increase (3)</i>	<i>Possible progress by 1981 (4)</i>
A. New cities				
Southampton/Portsmouth area	750,000	144,000	250,000	150,000
Bletchley area	17,000	4,000	150,000	75,000
Newbury area	20,000	3,000	150,000	75,000
B. Big new expansions				
Stansted (Essex)	—	—	100,000	75,000
Ashford (Kent)	28,000	3,000	100,000	75,000
Ipswich	120,000	19,000	60,000 +	60,000
Northampton	100,000	7,000	100,000	50,000
Peterborough	60,000	7,000	50,000 +	50,000
Swindon	90,000	14,000	50,000—75,000	50,000
C. Other expansions				
Aylesbury	27,000	6,000	All of these places seem to offer scope for an expansion of at least 30,000. At some of them, (e.g. Chelmsford and Southend) considerably more; though some of the growth could not take place before 1981.	
Banbury	21,000	3,000		
Bedford	65,000	8,000		
Chelmsford	60,000	7,000		
Colchester	60,000	8,000		
Hastings	65,000	-2,000		
Maidstone	60,000	8,000		
Medway Towns	170,000	24,000		
Norwich	120,000	14,000		
Poole	90,000	9,000		
Reading	120,000	16,000		
Southend	165,000	8,000		

Notes

1. Targets for planned increase (columns 3 and 4) are additional to natural increase (column 2).
2. At some of the places mentioned town expansion (mainly on a small scale) is already proceeding. They are Ashford, Aylesbury, Bletchley and Swindon.
3. The estimates of natural change are provisional and are made on the assumption that these places will continue to receive the same share of the total natural growth as they have received in recent years.

Fig. 56, was subdivided into 6 neighbourhood units, each of approximately 10,000 population, with one of the units incorporating the existing town. Other new towns, such as Crawley and Harlow, adopted much smaller neighbourhood units.

In contrast, the new town of 100,000 population planned at Hook (Hants) by the former London County Council, was linear in character

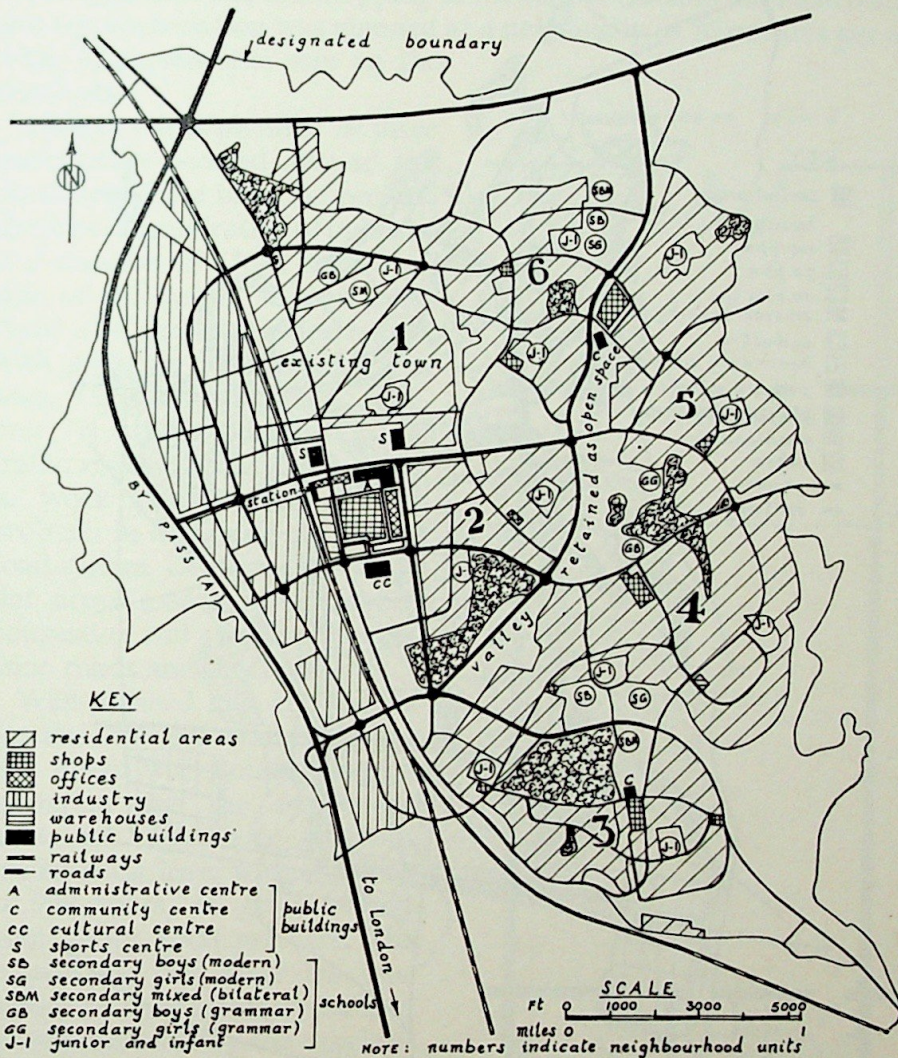


FIG. 56. Stevenage New Town—Layout plan.

along a spine road following the floor of a valley. A town collector road encircled the main built-up area of the planned town and linked the residential areas with the three industrial zones (see Fig. 57). The town centre provided for vertical separation of pedestrians and vehicles; cars, buses and lorries could drive straight into the heart of the town and park directly under their destinations, and the deck above would be fully

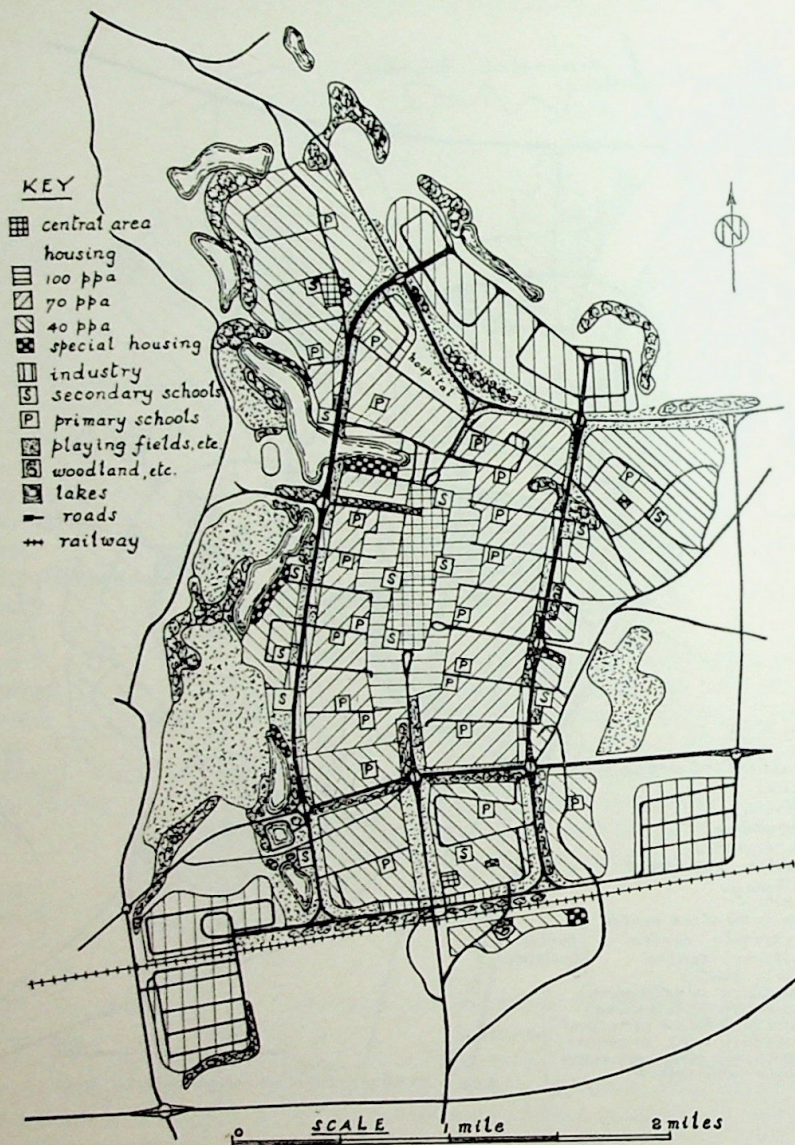


FIG. 57. Hook New Town—Layout plan.

developed as the focus of the town's comprehensive system of independent pedestrian ways and as the main enclosed shopping and business area.

The inner town was planned to absorb about 60,000 of the town's population, at a net density of 100 persons per acre, all within $\frac{1}{2}$ mile

walking distance of the shopping in the centre. Outside this zone residential accommodation was planned at a net density of 70 persons per acre, with 40 persons per acre on the outskirts.

Industry was planned in three main zones located around the outskirts of the town, to prevent the over-concentration of industry and creation of a 'one industrial' side of the town. This arrangement also provides industrialists with a choice between different sites. The main advantage, however, is traffic distribution, as traffic resulting from the journey to work produces the biggest problem in designing the town's road system. Dispersal of industrial areas assists in preventing congestion and avoiding uneconomic roads and junctions (14).

Well-planned and laid-out industrial sites are available in the new towns with housing accommodation for the employees. Industrial sites are generally available on lease with terms up to 999 years, at ground rents from about £300 per acre. The industrialist can build his own factory or have a factory built to his requirements by the development corporation. Some standard factories are also built, of which the most popular is probably the 'unit' or 'nursery' factory of about 2,500 ft² floor area. Fig. 58 illustrates a typical 'unit' factory, for which normal rents are 4s. 6d. to 6s. per ft² p.a.

Readers requiring further information on new towns are referred to *New Towns* by Osborn and Whittick (19).

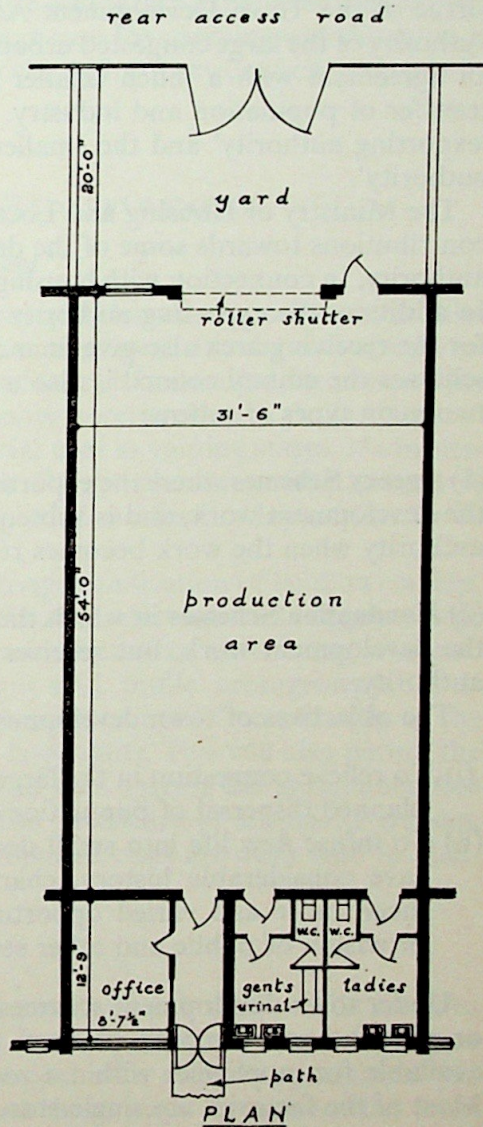


FIG. 58. Typical 'unit' factory.

Expanding Towns

The dispersal policy which prompted the new town schemes was later extended to the expansion of some of the smaller country towns, by virtue of the Town Development Act, 1952. Under this Act the local authority of the large congested urban centre, such as London, concludes an agreement with a much smaller provincial local authority for the transfer of population and industry. The large authority is termed the 'exporting authority' and the smaller authority is called the 'receiving authority'.

The Ministry of Housing and Local Government has power to make contributions towards some of the development expenses of a receiving authority, in connection with housing, water supply and main drainage. In addition, the exporting authority and sometimes the county council for the receiving area also give financial assistance. In some of the later schemes the county council is also a party to the agreement. There are two main types of scheme:

- (1) **Agency Schemes** where the exporting authority carries out the bulk of the development work, and is subsequently reimbursed by the receiving authority when the work becomes revenue producing.
- (2) **Nomination Schemes** in which the receiving authority carries out all the development work, but receives contributions from the exporting authority.

The objectives of town development schemes are twofold:

- (i) To relieve congestion in the large urban centre by assisting with the planned dispersal of population and industry.
- (ii) To infuse new life into small declining country towns, which often have considerable history, character and charm. Expansion will mean more and varied opportunities for employment and better provision of public and other services.

Under town development schemes, industrialists can build, purchase or rent factories on well planned industrial estates and houses are available for employees within a reasonable distance of the factories. Most of the factories are single-storey buildings containing small office blocks, and 'unit' factories are quite popular.

Probably the biggest difficulties experienced by the smaller and more distant receiving authorities, such as Thetford, Haverhill and Huntingdon, have been attracting suitable industry to their areas and the synchronising of housing and industrial construction programmes. The

provision of social services and amenities barely keeps pace with development in the early stages, and some of the quietness and character of the small town is lost as it becomes a bustling industrial town with a new life and purpose. Undoubtedly, more and larger expansion schemes are needed and there is probably a good case for carrying out this type of development on a regional basis or through county councils as part of a national plan (20).

PLANNING OF REDEVELOPMENT

Need for Comprehensive Development

One of the most urgent and complex problems facing urban authorities today is that of 'urban renewal'. Most towns and cities have evolved over a long period on a radial road pattern which is unsuited for present-day traffic requirements. Outside the inner core is often a girdle of mixed residential, commercial and industrial uses in varying stages of obsolescence, often termed 'twilight' or 'blighted' areas. Comprehensive development of these areas is essential if satisfactory layouts are to be obtained.

Comprehensive development envisages unification of land ownership, preferably by the local authority. Modern developments require large areas of land to permit the best use of modern techniques of mixed development, multi-level circulation and traffic arrangements. It is essential to combine the small awkwardly shaped freehold sites of the nineteenth century into reasonably large units. This will also permit the balancing of the more profitable land uses against the unremunerative ones, such as open space (21). The problems of displaced traders, selection of developers and redevelopment costs are dealt with in Planning Bulletin No. 3 (22).

Traffic Networks

The crux of town centre planning is traffic; through traffic requires diverting onto suitable relief roads, and an adequate circulatory road system needs to be introduced, coupled with sufficient peripheral car parking space and a network of pedestrian ways throughout the town centre (23). Fig. 59 illustrates the road, parking and pedestrian precinct proposals for Coventry.

The Coventry road network consists of

- (1) An inner ring road, for diversion of through traffic, built around the new city centre (some 1,600 yd in diameter), with an overall length of

2½ miles of dual 24-ft carriageways, and 9 grade separated junctions where it intersects the main radial roads.

- (2) An inner circulatory road to cater for public transport and service vehicles.
- (3) A comprehensive system of traffic-free shopping precincts serviced from the rear, as illustrated in Plates X and XI.

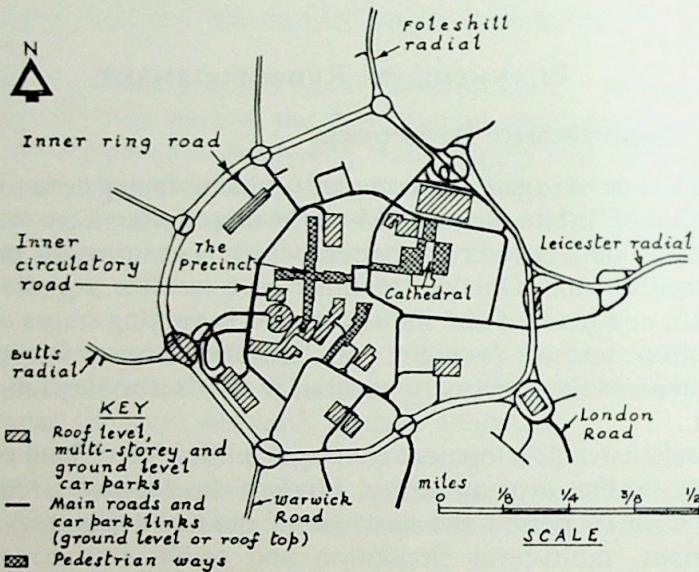


FIG. 59. Central area redevelopment, Coventry.

- (4) A system of pedestrian routes leading to the city centre, incorporating pedestrian subways.
- (5) Car parking areas with vehicular access from the inner ring and priority routes to business and shopping areas for long-term parkers.
- (6) An interconnected system of roof-top and multi-storey car parks in the central area for short-term parkers.

It is envisaged that the flow of traffic into the city centre will ultimately be controlled automatically, by means of electronic equipment at the main junctions of the radial roads with the inner ring road.

The private motorist needs to be able to park reasonably close to the town centre, whilst service traffic requires direct access to buildings. In addition to separation of pedestrians and vehicular traffic, it is therefore also advisable to segregate commercial vehicles from other vehicles. This has been successfully achieved at Birmingham where developers are

required, as a condition of planning approval, to provide off-street loading facilities, and specially designated roads are provided to take commercial or service vehicles along routes where no parking is permitted and from which pedestrians and city traffic, such as buses, are excluded (21).

Public transport needs to be able to penetrate as close as possible to the heart of the town or city, and bus stations, bus routes and even bus stops need careful planning.

Provision for Pedestrians

Modern town centres give priority to the pedestrian and proper segregation of central area operations is essential to provide safety,

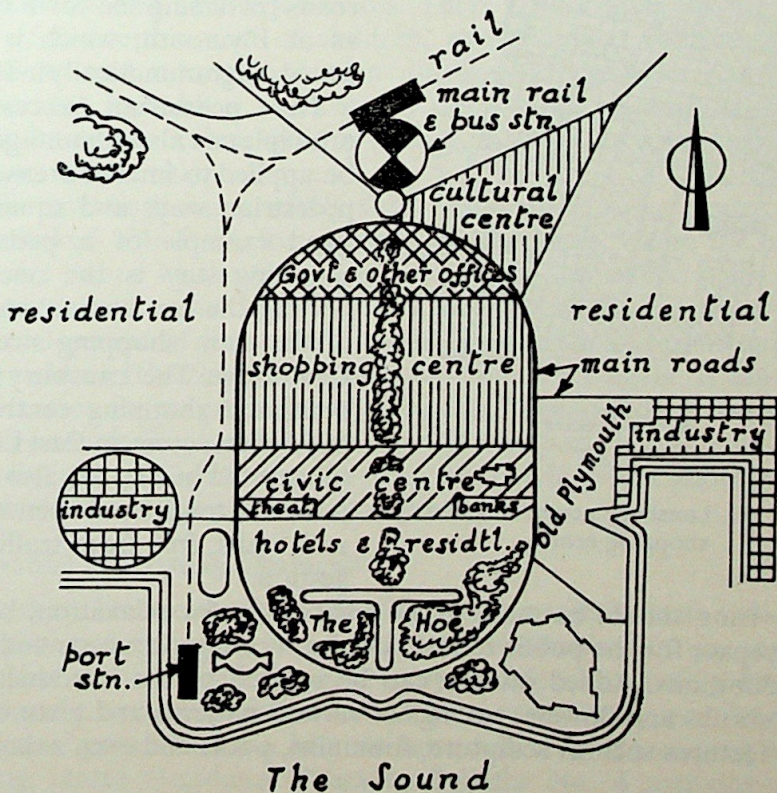


FIG. 60. Plymouth City Centre—Diagrammatic plan.

maximum concentration of use, amenity and comfort. Pedestrians and motorists can be kept apart, either by planning traffic-free precincts at ground level, or by planning for pedestrians and vehicles to move about at different levels. Separation was first attempted in this country on a large scale at Coventry, on the site of a severely war-damaged town centre,

and was adopted in many of the New Towns. Traders were at first apprehensive of these schemes, fearing loss of trade, but it has since been proved that the public prefers to carry out shopping free from noise, smell and the hazards of heavy traffic (24). This is a radical departure from most of the immediate post-war plans which showed wide tree-lined roads traversing the town centre, as at Plymouth, which is illustrated diagrammatically in Fig. 60.

The pedestrian access-only principle can also advantageously be applied to smaller areas, using pedestrian ways and squares. A good example of a pedestrian shopping way is the one connecting the bus station and one of the main shopping streets at Cambridge. The Lansbury neighbourhood shopping centre with pedestrian access, in East London (illustrated in Fig. 61) also incorporates a traditional open market with stalls, free from traffic congestion.

Provision should be made in the town centre for relaxation, by providing space for the public to rest, and for meetings, concerts and open-air exhibitions. Added interest can be secured by the introduction of trees, shrubs and flowers, pavings of various patterns and textures, and other features such as sculpture, fountains, pools and even aviaries.

Town Centre Uses

The best arrangement of shopping space is probably on two storeys,

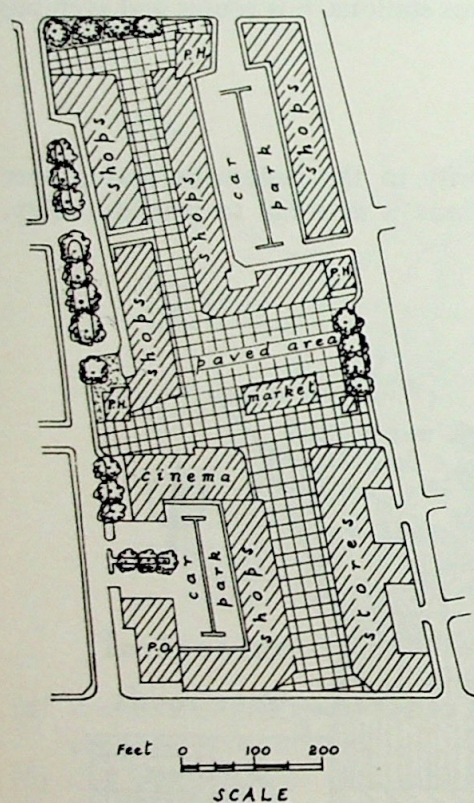


FIG. 61. Lansbury neighbourhood shopping centre.

interconnected by staircases, ramps and footbridges. This is well illustrated in Plates X and XI which show parts of the shopping precincts at Coventry, with extensive paved and tree planted areas and relatively inconspicuous underground public conveniences. The old cathedral closes the vista very successfully in the lower shopping precinct.

Due to the great concentration of buildings and uses in the town centre, land values are extremely high. Hence many redevelopment schemes are planning for a variety of uses at different levels. A scheme for part of the shopping centre at Liverpool, includes shops, retail markets, a hotel and a multi-storey car park, whilst a tall chimney shaft serving the central heating system for the development, incorporates a circular restaurant at the top (24).

The new shopping centres at the Elephant and Castle (London) and the Bull Ring (Birmingham) each provide a vast range of shopping facilities at different levels under one roof. For example, the Bull Ring scheme provides on four main floors, retail markets, 141 shops, departmental stores and ancillary services. There are facilities for the supervision and entertainment of children, open planned continental type restaurants and attractive garden displays all the year round. The development includes a seven-storey office block, a multi-storey car park and a new omnibus station—in fact, most of the component parts of a town centre (21).

Public buildings can usefully form part of the town centre or be closely linked with it as, for example, at Plymouth, where the council offices are linked to the town centre by paths and public open space. Other town centre uses include hotels, bowling alleys and dance halls.

Redevelopment of central areas will also provide an opportunity for people to live in the centres of towns and cities once again. It can be an ideal situation for people without young families and those living singly; with town centre shops, entertainments and transport close at hand. Some residential accommodation in the town centre will give it added vitality and some life and light in the evenings.

Preservation of Existing Character

Care must be taken when redeveloping to retain historic buildings, open spaces, outstanding trees and other desirable features, and to ensure that all new development is in sympathy with existing development in scale, materials and colour. In some cases it may even be advisable to ease pressures on a historic town centre by developing a new shopping centre elsewhere. Planning Bulletin No. 4 contains many excellent illustrations of modern development in town centres throughout the country (24).

PROTECTION OF AMENITIES

The Town and Country Planning Act, 1962, provides for the protection of amenities in a number of ways, including control of advertisements and the tree and building preservation order procedure. Further protection stems from green belt procedure and control of caravan development. Each of these aspects will now be briefly considered.

Advertisement Control

The control of advertisements is largely effected through the Town and Country Planning (Control of Advertisements) Regulations, whereby no advertisements can generally be displayed without the consent of the local planning authority, except where the advertisements have 'deemed consent'. In rural or other areas which are considered to need special protection of amenity, 'areas of special control' may be established, with the approval of the Minister, and no advertisements can be displayed in these areas.

Advertisements which have deemed consent include functional advertisements of local authorities, statutory undertakers, etc. (e.g. bus stop signs), miscellaneous advertisements relating to premises on which they are displayed (e.g. professional, business or trade plates) and certain temporary advertisements (e.g. 'For Sale' or 'To Let' boards). A local planning authority may require an advertisement displayed with deemed consent to be the subject of an application for express consent under the 'challenge procedure'. When considering advertisement proposals a local planning authority must pay regard to the character of the area and the purpose of the advertisement.

Preservation of Trees and Woodlands

Provision is made for the preservation of trees, groups of trees and woodlands by tree preservation orders, made by local planning authorities and confirmed by the Minister of Housing and Local Government. When in force, a tree preservation order prohibits the cutting down, topping, lopping or wilful destruction of trees, except with the consent of the local planning authority. It may also provide for the replanting of a woodland area, felled in the course of forestry operations permitted by a tree preservation order. Contravention of an order carries liability to a fine. Tree preservation orders should only be applied where the felling of the tree(s) would have an appreciable effect on the beauty of the area (see Town and Country Planning (Tree Preservation) Regulations).

Preservation of Buildings of Special Architectural or Historic Interest

Building preservation orders, made by local authorities or local planning authorities and confirmed by the Minister of Housing and Local Government, restrict the demolition, alteration or extension of such buildings. Work carried out in contravention of an order carries liability to a fine, but urgent works in the interests of safety, health or preservation of the property may be carried out provided notice is given to the local planning authority. The Minister prepares lists of buildings of special architectural or historic interest and informs the local authorities and owners and occupiers of the buildings.

Waste Land

Local planning authorities are empowered to take action with regard to neglected land which has become unsightly or offensive, by serving an abatement notice on the owner or occupier of the land. Non-compliance with the notice carries liability to a fine.

Green Belts

'Green belts' are areas of land, near to and sometimes surrounding towns, which are kept open by permanent and severe restrictions on building. The purpose of a green belt may be to prevent two towns joining, to limit the expansion of a town or to prevent groups of towns merging into one solid urban mass. One of the best examples of a green belt is the zone prescribed around London in the Greater London Plan. (8), commencing approximately 12 miles out from the centre of London with an average depth of about 8 miles.

It is very difficult to obtain permission to build in a green belt, and an applicant would be required to show that the building was needed for purposes appropriate to the green belt (e.g. agricultural purposes) or some other special purpose. The inclusion of land in a green belt does not give the public any additional rights of access, and the greater part of land in green belts remains in private ownership and is predominantly farmland (25).

Development in the Countryside

Local planning authorities are anxious to prevent further urban sprawl and the building of isolated houses in the countryside, in order to protect the open countryside in the interests of those who live there and the many more people who live in towns and visit the country for enjoyment. Many villages could satisfactorily absorb a number of single new houses

or small groups of houses without losing their character. Furthermore, the additional residents would help to provide a living, growing and varied community and also help to pay for more modern services.

Building of houses in the open country is strictly controlled and is usually limited to such persons as farmers and essential farm workers, who have a special need to live in these locations. Permission will not usually be granted to enlarge isolated groups of houses or extend 'ribbons' of existing houses. On the other hand, an application to build a new house in a small gap between existing houses will normally be permitted, in the absence of special reasons to the contrary (26).

Caravans

No land may be occupied as a caravan site without a site licence obtained from the local authority, subject to certain exemptions. These exemptions include the use of a caravan within the curtilage of a dwelling house, if incidental to the enjoyment of the dwelling, and for limited seasonal use by agricultural and forestry workers, workers on building and civil engineering sites and travelling showmen.

Planning permission is required to cover planning considerations, such as the suitability of the land for a caravan site and whether the use should be limited to holiday purposes and summer months. The licence will cover aspects such as internal amenity, sanitation, safety, density and similar requirements. Detailed information on the location, layout and landscaping of caravan sites or parks can be obtained from the Ministry publication *Caravan Parks* (27).

Other Developments

Applications for the working of gravel pits, brick-fields, etc. need special consideration and the insertion of conditions relating to subsequent restoration of the landscape. Proposals for petrol filling stations and cafés must not injure amenity or reduce road safety. Proposed overhead electricity lines can sometimes be resited to cause less harm to the landscape, but high cost prevents them being laid underground.

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CHAPTER ELEVEN

Housing Development

THE responsibilities of municipal engineers for housing work vary between authorities. In very large authorities the houses and flats will often be designed by the city or borough architect, and the municipal engineer will be responsible mainly for the provision of roads and engineering services. In the medium-sized authority the engineer may also design the dwelling units, and in small authorities the engineer is often responsible for the works of maintenance and improvement to local authority houses.

TYPES OF DWELLING AND ACCOMMODATION

Main Categories

There are numerous types of dwelling built by local authorities, varying both in size and in physical characteristics. The majority of dwellings are still provided in houses, which can be detached, semi-detached or built in terraced blocks, and the number of bedrooms can vary from one to four to suit different sizes of family. Special accommodation is needed to cater for aged persons, disabled persons, single workers, students and apprentices.

In recent years more emphasis has been placed on the construction of flats and maisonettes, generally with a view to securing higher densities and the fuller use of highly priced land. The best planned layouts often contain a mixture of varying types of dwelling.

Two-storey Houses

Local authorities have, over the years, received considerable guidance from the Ministry of Housing and Local Government on the design and

layout of dwellings. This guidance has been largely aimed at achieving good housing standards yet, at the same time, securing economical designs and layouts. The Housing Manual (see reference 1 at the end of this chapter) and the 1952 supplement (2) illustrated many types of basic design for use by the local authorities. These designs provided for both semi-detached and terraced houses, accommodating either four or five persons.

The four-person houses have two bedrooms and the five-person houses have three bedrooms. A variation to this general rule is the three-bedroom house which has one double and two single bedrooms, to house a family of four with two older children of opposite sex.

There are three basic designs:

- (1) Living room, small dining room and a working kitchen.
- (2) Large living room including a dining area, which may be in the form of a recess, and a working kitchen.
- (3) Living room and large dining kitchen.

In all cases access to the ground floor rooms is obtained from a front hall, but access to the first floor may be taken from a staircase rising from the hall, or from a living room or dining area, where the ground floor rooms are centrally heated and the heat is able to rise up the stairwell and circulate through the bedrooms (open planning).

TABLE 10. MINIMUM HOUSING STANDARDS

<i>House Type, etc.</i>	<i>Room</i>	<i>Minimum Floor Area in ft²</i>
Kitchen/living room house	kitchen/living room	180
	sitting room	110
	scullery	50
Working kitchen house	living room (no separate dining space)	180
	living room plus dining space	225
	working kitchen	90
Dining kitchen house	living room	160
	dining kitchen	110
Bedrooms	first bedroom	135
	other double bedrooms	110
	single bedrooms	70

Note: Aggregate living space (combined area of ground floor living room, sitting room and kitchen) should not be less than 280 ft² for a 2-bedroom house for 4 persons or 320 ft² for a 3-bedroom house for 5 persons.

With terraced houses, access to the rear of the house can take one of several different forms. The more orthodox arrangement consists of a common covered passageway between adjacent houses, with storage accommodation provided in outbuildings at the rear of the block. Another form of layout provides access through an enclosed store built within the walls of the house, which eliminates the draughty covered passage and provides a sound barrier between the ground floor rooms of adjacent houses. Other schemes provide for a store, containing the dust-bin, at the front of the house with access through the kitchen to the rear, or alternatively access can be provided through the hall at the front and the store at the rear of the house.

The Ministry publication *Houses 1952* (2) laid down the minimum areas of living space given in Table 10.

Other Types of Accommodation

Houses, 1953 (3) included plans for the following three types of accommodation:

- (1) Frontage-saving terrace houses and two-storey blocks of flats, for layouts where access is provided to both sides of each terrace block. Frontages between dividing walls of houses are reduced to 21 ft for a three-bedroom house, 19 ft 6 in. for a two-bedroom house and 16 ft 6 in. for a two-bedroom house incorporating a dining-hall.
The two-storey two-bedroom cottage flats are particularly suitable for small families and are more economical than two-storey houses.
- (2) Designs to link terraces of houses sited at right-angles or parallel to one another at corner sites. The plans show two-storey flats for external corner blocks and two-storey houses and flats for internal corners, to accommodate small households and elderly people, with wide paved covered ways passing through the blocks.
- (3) Three-storey blocks of flats in which one staircase serves four flats on each floor.

Housing of Single Workers, Disabled Persons, etc.

The Ministry publication *Housing for Special Purposes* (4), deals with the provision of housing accommodation for elderly people; single workers, students and apprentices; disabled persons; district nurses and midwives; and higher income groups. Housing of elderly people will be dealt with in some detail later in this chapter.

It was felt that single workers, students and apprentices were best accommodated in hostels, either in a residential area or near the

business or commercial area of a town. The building should preferably be designed with common rooms on the ground floor and private rooms above, with central heating throughout, but with heating in the private rooms capable of control by the tenant. Bedrooms/studies should have a minimum floor area of 108 ft².

Full communal meals service and communal laundries were recommended. A warden should be employed to supervise the running of the hostel, and he should be provided with a self-contained flat with at least two bedrooms.

Dwellings for disabled persons need to be specially designed bungalows with ramped entrances, wide passages and doorways, and special fittings. A plan of a disabled person's bungalow is shown in Appendix E of the Supplement (4).

Latest Housing Standards

In more recent years there has been a change of approach to the design of housing accommodation, stemming from *Homes for Today and Tomorrow* (5). In this publication accommodation recommendations are not based on minimum room sizes, but on functional requirements and levels of performance, with minimum overall sizes for the dwelling related to the size of family. There should be space for activities demanding privacy and quiet, for satisfactory circulation, for adequate storage and to house new household equipment, in addition to a kitchen arranged for easy housework and with sufficient room in which to take at least some meals.

The wide range of activities which take place in an average house, their sequence and the space they require are delightfully illustrated in *Space in the Home* (6). This publication clearly indicates the fundamental principles involved in the design of a dwelling to ensure the best possible use of interior space.

The planning of kitchens often leaves much to be desired and the following suggestions contained in *Meals in Modern Homes* (7) deserve special consideration:

- (1) Main equipment in the kitchen should be arranged in the order of work surface/cooker/work surface/sink/work surface, and the kitchen should be designed to make this possible, either in the form of an 'L', a 'U' or a straight line.
- (2) There should be adequate storage space adjacent to the sink and cooker for china, glass, cutlery and kitchen utensils in frequent use.
- (3) The working area of a kitchen should receive good light from

- windows and it should be at one end of the room, with access doors together at the other.
- (4) Where there is a living room and a kitchen, both should have sufficient space for a dining table, with easy access by a hatch or door from the kitchen to the meals area in the living room.
 - (5) A separate store cupboard for dry goods should be provided in the kitchen and there should also be space there for a refrigerator.
 - (6) Much trouble is experienced with condensation in kitchens and larders, some being caused by inefficient cooking methods and lack of understanding of the principles of ventilation.

TABLE 11. LATEST RECOMMENDED MINIMUM HOUSING STANDARDS
(Extracted from *Homes for Today and Tomorrow* (5) often referred to as Parker Morris standards)

A home to be built in the future for occupation by:						
	6 people	5 people	4 people	3 people	2 people	1 person
should be designed with a net floor area in ft ² of at least:						
3-storey house	1050	1010	—	—	—	—
2-storey centre terrace	990	910	800	—	—	—
2-storey semi. or end		880	770	—	—	—
Maisonette						
Flat	930	850	750	610	480	320
Single storey house	900	810	720	610	480	320
General Storage Space						
Houses	50	50	50	45	40	30
Flats and Maisonettes						
Inside the dwelling	15	15	15	12	10	8
Outside the dwelling	20	20	20	20	20	20

Note: Net floor area is the area on one or more floors enclosed by the walls of a dwelling, including partitions, staircases, chimney breasts, etc.

Fuel Storage. A minimum of 12 ft² is recommended for one appliance and 20 ft² for two appliances and in rural areas (increased area also required in Smoke Control Zones).

Fittings and Equipment. It is recommended that W.C.s should be provided as follows:

- (1) In 1, 2 and 3-person dwellings, 1 W.C. is required and may be located in the bathroom.
- (2) In 4-person one, two or three-storey houses and two-level maisonettes and in 5-person flats and single-storey houses, 1 W.C. is required in a separate compartment.
- (3) In two or three-storey houses and two-level maisonettes at or above the minimum floor area for 5 persons, and in flats and single-storey houses at or above the minimum floor area for 6 persons, 2 W.C.s are required, one of which may be in the bathroom.
- (4) Where a separate W.C. does not adjoin a bathroom, it must contain a wash-basin.

Kitchen Fitments. In 4 or 5-person dwellings a minimum of 80 ft³ of storage space should be provided for all purposes.

Bedroom Cupboards. Except in main bedroom, built-in cupboards should be provided at the rate of 2 ft of rail per occupier (clear internal depth not less than 1 ft 9 in.).

TABLE 12. RECOMMENDED PROVISION OF ELECTRIC SOCKET OUTLETS

<i>Part of dwelling</i>	<i>Desirable provision</i>	<i>Minimum provision</i>
Working area of kitchen	4	4
Dining area	2	1
Living area	5	3
First or only double bedroom	3	2
Other double bedrooms	2	2
Single bedrooms	2	2
Hall or landing	1	1
Store/workshop/garage	1	—
Single study bedrooms	2	2
Single bedsitting rooms in family dwellings	3	3
Single bedsitting rooms in self-contained bedsitting room dwellings	5	5

Heating of Dwellings

It is recommended that a minimum standard of heating should be 55°F (13°C) for the kitchen and circulation areas and 65°F (18°C) for

living and dining areas, when the outside temperature is 30°F (−1°C)
(5). Various fuels are available for this purpose:

- (1) Solid fuel normally gives the lowest costs, except for short-period heating, but it is the least convenient and requires storage space.
- (2) Oil is generally cheaper than gas or electricity but more expensive than solid fuels, needs storage accommodation but is quite well suited for short-period heating.
- (3) Gas is clean, convenient and well suited for short-period heating, but is usually quite expensive.
- (4) Electricity is the most convenient but also the most expensive. Operating costs can be reduced by the use of thermal storage systems using electricity at the cheaper off-peak rates, but this results in some loss of flexibility and some on-peak electricity will still be required.

Space heating systems can be installed to heat the ground floor only or the whole of the dwelling. The four main systems are:

- (1) Open fire with a high output back boiler and two radiators (using an immersion heater or gas water heater for heating water in the summer).
- (2) Independent boiler fired by solid fuel, gas or oil, coupled with 2 to 4 radiators.
- (3) Warm-air system, often gas fired.
- (4) Thermal storage system, often incorporating electric underfloor heating with cables embedded below the ground floor.

HOUSING DENSITIES

Housing densities are expressed in a number of different ways. In the pre-war planning schemes residential densities were usually expressed in houses per acre, but in more recent times it has become customary to use persons per acre (population density) or habitable rooms per acre (accommodation density), as these give the developer a greater degree of flexibility in his choice of dwelling types. A 'habitable room' is a living room or bedroom, but not a kitchen or bathroom. Population density can be converted to accommodation density by deciding on the average number of persons living in one room, usually about 1.0 (occupancy rate).

The density normally used is that of 'net residential density'; being the population (or accommodation) divided by the acreage, including

dwellings, gardens, any incidental open space (e.g. children's play spaces or parking spaces for visitors' cars) and half the width of boundary roads (up to a maximum of 20 ft). Shops, schools and most open spaces are excluded. 'Gross residential density' applies to a neighbourhood as a whole, while 'overall residential density' applies to a town as a whole.

In the garden cities, in the new towns of the immediate post-war period and in most of the earlier post-war local authority housing schemes, net residential densities of about 12 houses to the acre were used. Many arguments were put forward as to why this particular density should not be exceeded.

It was argued that 12 houses to the acre was a good practical density, which could be applied to varying orientations without overcrowding and overshadowing. It permitted reasonable distances between houses, giving satisfactory street pictures with suitable depths of front garden and ample back gardens. Space was available for kitchen gardens, which are generally cultivated far more intensively than farmland by spare-time labour, which would not otherwise contribute to food production.

In 1962, the Ministry of Housing and Local Government, called for higher residential densities (8). The Ministry publication *Residential Areas—Higher Densities* pointed out that the population of England and Wales was increasing by about 250,000 a year, and all available data indicated that the rate of increase would be maintained. People marry younger and live longer, and greater prosperity enables more families to have a home of their own, thus increasing the number of households. Furthermore, the occupancy rate has fallen from 3.3 to 3.0 persons per house between 1951 and 1961.

The relief of overcrowding, new roads, schools and open spaces, all require more land. Hence the plea for higher residential densities was made to reduce the total demand for land, to help preserve the countryside and protect good agricultural land. Substantial savings in land could be secured by increasing the net density to 40 persons per acre, particularly when some housing development is proceeding at about 24 persons per acre (about 8 houses per acre). It is further shown that net densities of 60 persons per acre (about 20 dwellings per acre) are practicable with two-storey houses, whilst a mixture of two and three-storey houses and some three or four-storey flats can produce net densities of up to 90 persons per acre. Higher densities can be obtained by introducing tall blocks of flats, but these need not predominate until net densities of 140 persons per acre are reached.

On the financial side, it is pointed out that as the permitted density rises so the cost of land increases, although the cost of land per dwelling decreases. Building costs decrease as densities rise up to 60 persons per

acre, due to the greater use of terraced blocks, but above this density building costs rise sharply. Service costs (roads and engineering services) decrease with more compact development.

The effect of increasing densities on building costs at medium and high densities is clearly indicated in Design Bulletin No. 7 (9). For instance, taking an average of 3 persons per dwelling, the average late 1962 costs per person at a density of 80 persons per acre (p.p.a.) were £578, £736 for 120 p.p.a., £852 for 160 p.p.a. and £920 for 200 p.p.a.

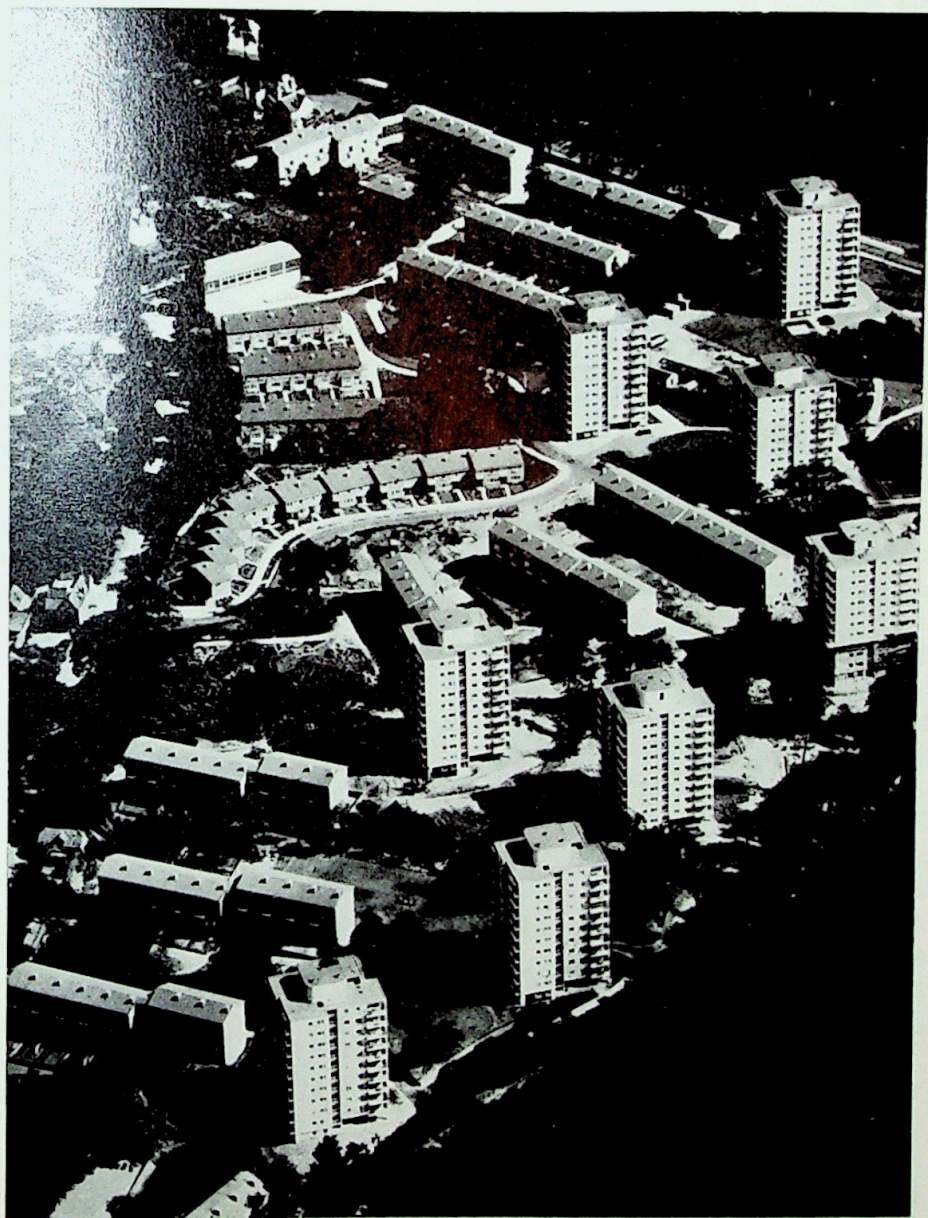
The Ministry accordingly require development to proceed in the 40 to 60 p.p.a. range as far as possible. In the conurbations and surrounding areas, higher densities still may be needed. Densities exceeding 100 p.p.a. are far from ideal but they may well meet the needs of families without small children, who prefer to accept the limitations of flat life, in order to live near their work or in their home town, rather than to have to leave the district altogether. The call for higher residential densities will probably not be generally welcomed but the Ministry have presented many valid arguments for its adoption. Their use calls for considerable skill in the planning of housing schemes.

USE OF FLATS

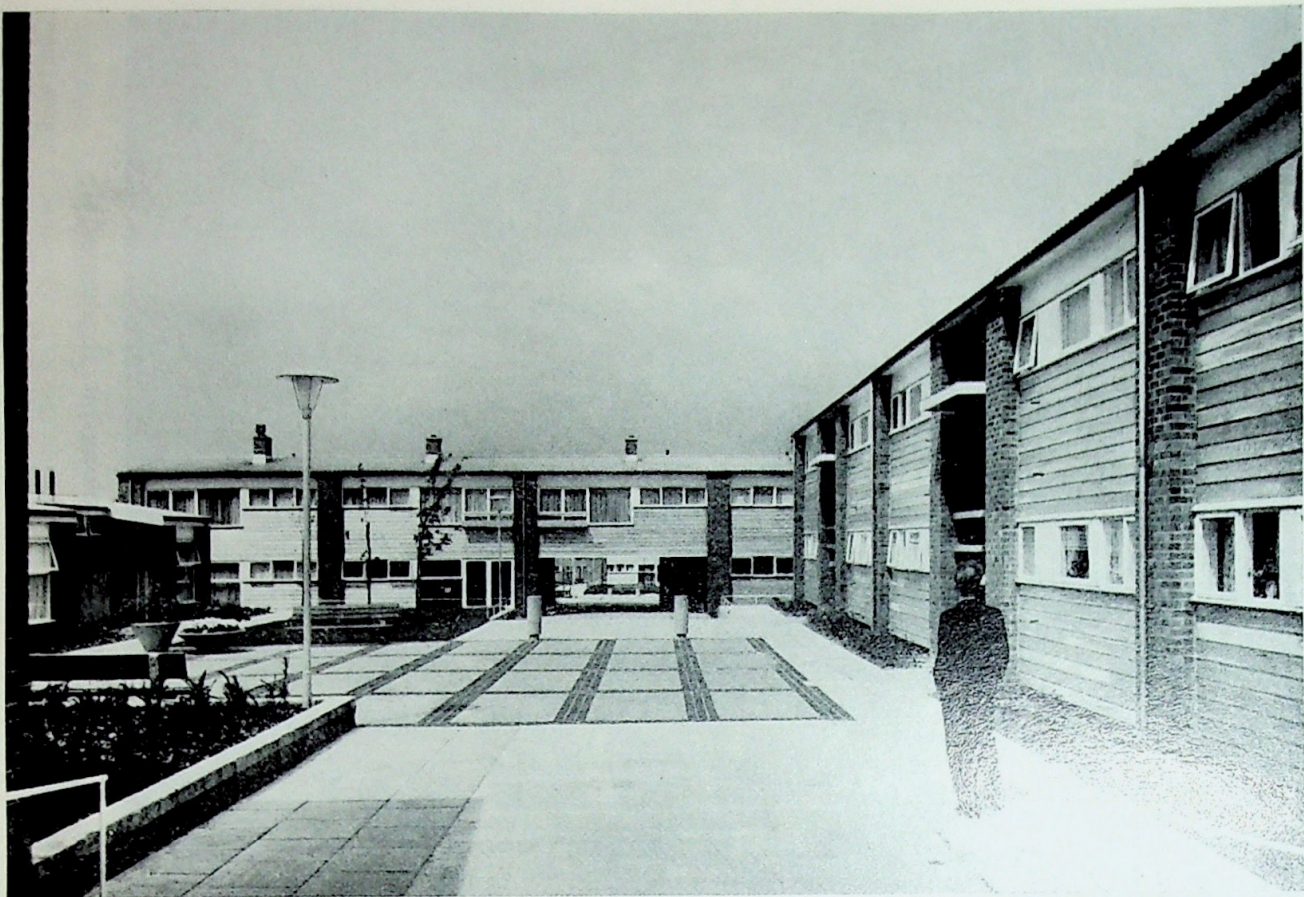
Need for Flats

There is a growing need for flats, particularly in the larger urban areas, to provide housing accommodation at very high densities. The redevelopment of central areas of obsolete high density housing, the carrying out of extensive road widening and improvement schemes, the high cost of building land and the desire to restrict peripheral growth have all tended to highlight the necessity for extensive residential development at high densities in the larger towns and cities.

Very attractive layouts can be achieved by using a 'mixed development' of blocks of differing heights. The Government publication *Flats and Houses* (10), shows various alternative layouts for the same site giving densities of 100, 140 and 160 habitable rooms per acre (h.r.a.), and gives an indication of the variety of alternatives available. The basic objective is to attain the required density as economically as possible by limiting the proportion of dwellings in high buildings. For instance, with densities up to 100 h.r.a. it is desirable to provide the maximum amount of accommodation in two-storey houses, which are each approximately £250 to £350 cheaper than four-storey maisonettes. With higher densities, the aim should be to secure a high proportion of



XII Mixed Development, Roehampton



XIII Old Persons' Housing Scheme, Crawley New Town

four-storey maisonettes, which will probably be about £500 to £600 cheaper than dwellings in high blocks of flats.

Flats and Houses also shows how graphs can be used to apportion the proposed development between the various types of building block. The siting of the buildings will also have to conform to the daylighting and sunlighting standards detailed in Appendix B of *Flats and Houses*. Plate XII illustrates a typical scheme of 'mixed development', of 11-storey tower blocks of flats, four-storey maisonettes and two-storey houses, with a net density of about 100 persons per acre, skilfully blended together in a beautiful landscape (former London County Council, Alton Estate, Roehampton).

Types of Flat

A variety of different types of flat are in use and some of the principal categories will now be described:

Tower Blocks of 11 storeys or more in height are mainly provided to accommodate smaller families. A common arrangement of dwellings is about 50 per cent one-bedroom and 50 per cent two-bedroom flats. Access is obtained in a variety of ways—daylighted common hall, enclosed common hall, cross-ventilated common hall or enclosed central corridor. Typical arrangements would be 4 flats per floor with the first three forms of access and 8 flats per floor with corridor access. There would probably be two staircases and two lifts in all cases.

High Slab Blocks are mainly used where it is not practicable to house all the larger families in houses or four-storey maisonettes. The slab blocks, rectangular in plan, may consist of 4 or 5-person living units arranged as flats or maisonettes. Access may be by balconies, corridors or staircases. The maisonettes are often arranged as three-floor units, whereby access to two maisonettes is obtained from the intermediate floor via halls and staircases, with the larger bedroom to each dwelling also located on this floor. The lower floor contains the living and dining areas, kitchen, bathroom and smaller bedroom for one dwelling, and the upper floor contains similar accommodation for the other dwelling.

Four-storey Maisonette Blocks usually consist of 3-bedroom units spread over two floors, with access to upper dwellings by a balcony served by a common staircase.

Three-storey Flats usually contain 2 and 3-bedroom flats (2 on each floor) served by a common staircase. All the rooms may be entered

from an entrance hall or access to the bedrooms may be obtained through a separate inner lobby. Other variations are working-kitchens and dining-kitchens, which are well illustrated in *Flats and Houses*.

Three-storey Houses in terraced blocks form a convenient and economical way of housing large families. Where densities are of the order of 100 to 115 h.r.a., if this type of block is used in conjunction with three-storey corner flats and four-storey blocks of maisonettes high blocks will not be needed.

Typical designs are illustrated in *Flats and Houses* and incorporate:

<i>Floor</i>	<i>Scheme 1</i>	<i>Scheme 2</i>
Ground floor	Hall, store and dining/kitchen	Hall, garage and all-purpose room
First floor	Living room, bathroom and bedroom	Living room and working kitchen
Second floor	3 bedrooms	3 bedrooms and bathroom

Flat Costs

The Cost Research Panel of the Royal Institution of Chartered Surveyors conducted a number of comprehensive cost investigations into the cost of flats and houses (11). The Panel found that there were large variations in the cost of construction of multi-storey flats, and that they cost $1\frac{1}{2}$ to 3 times the cost of two-storey houses when broken down to the comparable unit of the ft² of floor area (1955 costs).

Some additional cost is unavoidable on multi-storey schemes arising from higher constructional costs, provision of common access areas, fire-proofing requirements and added amenities, such as lifts, clothes drying facilities, refuse disposal installations, central heating, pram and cycle stores, children's playgrounds and landscaping.

A comparison of the relative costs of two-storey houses and eight-storey flats showed the following proportional costs per ft² for the eight-storey flats when broken down into the main component parts (taking 1.00 as the basis for two-storey houses).

Substructure	1.63
Superstructure	1.97
Internal finishings	1.40
Fittings and services	2.72
Total cost (relative)	1.96

Higher prices also result from less competition for multi-storey work and possibly from the use of new constructional methods and materials. The Panel felt that some of the designs were uneconomical and that there was a great need for cost planning by quantity surveyors during the design stage of projects.

Consideration should also be given to the probable cost of different patterns of development. It was generally found that very high densities were achieved most economically by a combination of a few very high blocks with a much larger amount of lower development, usually of two or three storeys in height. One of the first problems is accordingly the need to find the optimum combination of high and low blocks to give the required overall density.

The Building Research Station has also issued a digest on design, building methods and cost of multi-storey flats (12). This digest gives comparative costs of different constructional methods and indicates ways in which costs can be reduced (e.g. careful detailing of concrete members to simplify formwork and use of plate floors to eliminate beams).

Flats and Houses also contains a number of useful cost studies covering different site layouts and block designs.

Access

Access to flats is usually obtained in one of four main ways:

- (1) **Balcony or Gallery**, which is also suitable for maisonettes, but tends to be noisy and may restrict privacy. In some positions, exposure to wind and weather makes this form of access unsatisfactory.
- (2) **Lobby or Balcony**. A cross-ventilated lobby or a small semi-private balcony open to the air gives a reasonable degree of privacy, but the cross-ventilated lobby can be draughty and result in considerable heat loss.
- (3) **Staircase**, commonly used in blocks up to five storeys in height, giving full protection from the weather and high standard of privacy but may also produce feeling of isolation.
- (4) **Common Hall or Corridor**, not exposed to the weather. Common hall often used to give access to 4 flats on each floor of a tower block and corridors make it possible to serve more flats from common lifts and staircases (10).

Lifts

Lifts are necessary in blocks of flats exceeding three storeys in height, and in blocks of maisonettes exceeding four storeys. In buildings of more than six storeys, two lifts are required to cope with household removals, breakdowns, servicing, repairs, re-roping, etc. Lifts should be able to take eight persons each and the distance from a lift to a dwelling entrance should not exceed 150 ft. Some local authorities have avoided the need for lifts in blocks of flats, up to seven storeys in height, by siting the flats on hillsides and introducing elevated walkways, often giving access to the lower five floors.

Heating and Hot Water

With blocks up to five storeys in height, a common arrangement is a solid fuel fire in the living room with a back boiler, a hot water circulatory system and an electric immersion or gas convector heater for summer or emergency use. For blocks above this height, central heating and hot water supply is the common practice, to avoid numerous heating appliances and fuel stores, with consequent loss of floor space.

Numerous heating systems are available ranging from conventional central heating with radiators or skirting convectors, to electric floor warming and warm air heating. Heating can be applied to all or part of the dwelling and be under the control of the landlord or tenant. The Building Research Station points out that landlord control may be a source of complaint, due to people being on shift work, vagaries of the British climate and methods of charging, and the Station also gives a wealth of information on living room temperatures obtained and heating costs of various systems (13).

Experience in Sweden and Denmark has shown that considerable savings can be effected by using 'district heating' systems to supply heat and hot water to a residential district or even a complete town, mainly using thermal stations.

Private Balconies

The main functions of private balconies are to provide access to the open air and a sitting out place, but they may also give access to refuse arrangements and provide space for hanging washing. They are best entered from the living room or kitchen or both, with easy access for prams and no dangers to children. A minimum depth of 3 ft 6 in. (dwelling to balcony railing) and a minimum area of 45 ft² has been recommended by the Ministry (10), but their provision cost about £150 in

1961 (5). Consideration should be given to the provision of shelter and of screening between balconies.

Refuse Disposal

In three-storey blocks of flats and four-storey maisonettes a common arrangement is to provide small containers in each dwelling, but in larger blocks refuse chutes are normally provided, as described in Chapter VII. As indicated by the Institution of Municipal Engineers, a vast field of research is open to determine the best methods for the disposal of refuse from blocks of flats. Sink grinders, communal water-borne systems, smokeless incinerators and calcifiers (low temperature incinerators which sterilise and dehydrate putrescible refuse and reduce its bulk) are all worthy of the fullest consideration (5).

Other Matters

Storage space is needed for flat tenants, and in low blocks is normally provided in outbuildings at the rate of about 20 ft² per dwelling. With higher blocks, prams are best stored inside the dwelling and other storage place is normally provided on the ground floor or in the basement. Where fuel storage is needed, this is best provided inside the dwelling with a minimum area of 9 ft² served through a delivery hatch.

For washing and drying of clothes, small shared laundry rooms are generally preferred, equipped with a washing machine, washboiler, sink with wringer and two or more drying cabinets. Outdoor drying grounds are usually quite popular with tenants who are in reasonably close proximity to them.

Other aspects warranting special consideration are the provision of children's playspaces, the layout of the immediate landscape and safety precautions (5).

OLD PERSONS' DWELLINGS

General Needs

Many elderly people who are still fit prefer to live in fully self-contained dwellings. The most popular form of dwelling is the single bedroom bungalow, with a living room, small kitchen and combined bathroom and W.C. There are also a large number of elderly persons who, by reason of age or infirmity, are not able to manage entirely on their own in normal type bungalows. Where these persons can be

relieved of some of the burdens of normal tenancy, and given friendly oversight and a limited amount of assistance by a warden, they can continue to lead independent lives and remain an integral part of the community.

Design Factors

Many aspects of designing for old people are covered in the Ministry Design Bulletin No. 1 (14).

Heating and Lighting. Central heating is favoured with a preference for under-floor heating, to maintain a temperature of 70°F (21°C). The use and operation of electric under-floor heating is well covered in a Building Research current paper (15). Open fires are unsuitable for old people, although radiant fires can be installed to advantage.

A high level of illumination is needed and the cutting out of glare from the sky by blinds or external high-level louvres. Minimum daylight factors of 2 for kitchens, 1 for living rooms and bedrooms and $\frac{1}{2}$ for circulation space should be adopted. Tungsten filaments are likely to prove more satisfactory than fluorescent lights.

Fittings. Side-hung wooden casements or horizontal sliding windows and doors with lever handles, fixed at 36 in. above the floor, are generally to be preferred. Stairs should have an easy going, preferably at an inclination of about 30°, and should be provided with handrails on each side.

Baths should have their rims not more than 15 in. from the bathroom floor; also a 1½ in. diameter vertical pole covered with non-slip material, a handle on the wall or bath 36 in. from the tap end of the bath and a wooden seat across the bath are all very helpful. Inclined rails on walls beside a W.C. and a 15 in. seat height are useful aids. Both baths and W.C.s in flatlets should be provided with door locks that can be opened from the outside in an emergency and with bell pushes.

Socket outlets should be ample in number and be sited about 33 in. to 36 in. from the floor, and maximum use should be made of two-way switches.

Grouped Flatlets

In recent years many schemes of grouped flatlets have been implemented. Basically these schemes usually provide a number of centrally-heated flatlets, shared baths and W.C.s, some communal facilities and a warden's residence. The flatlets can be designed in a number of different ways, with bed-sitting rooms and kitchen fittings in cupboards, with

separate kitchenettes, or with separate bedrooms. Another alternative is to locate the beds in bed recesses in the living rooms, which can be closed off with curtains.

Baths are generally shared in the ratio of about 1 bath to 3 to 5 persons, and W.C.s in the ratio of 1 to 2 or 3 persons. The communal facilities invariably include a common room where the tenants can sit, read, talk, play cards and often watch television. There is, however a strong case for installing the television set in a separate room. Communal laundries are often provided and common equipment consists of a deep sink and drainer, wringer and possibly a washing machine. Heated drying rooms or drying cabinets are frequently provided in addition to outdoor drying spaces. One or two guests rooms are often provided, normally adjoining the warden's quarters, the latter usually consisting of a 2-bedroom dwelling.

The warden is normally a married women between 30 and 55 years of age and often has nursing experience. The husband follows his normal occupation, but usually helps with repair jobs and upkeep of the garden. The warden's duties vary but they are largely those of the 'good neighbour' to help and advise where necessary, and clean the communal parts of the building.

Useful information on the operation of grouped flatlets for old people and a number of plans of operative schemes are shown in the Ministry Design Bulletin No. 2 (16).

Plate XIII illustrates an attractive housing scheme for elderly persons at Crawley New Town. This attractive development is planned as a series of connecting courts, which descend by way of gently sloping ramps. It possesses an outstanding sense of enclosure, between the brick and weather-boarded houses. The courtyards are paved with precast concrete slabs and squares of of *in situ* exposed aggregate panels laid between courses of bricks. The grassed area, ornamental trees and precast concrete bollards and flower tubs all add character and interest.

INDUSTRIALISED BUILDING

Local authorities are constantly being urged by the Government to use industrialised building in their housing programmes, in order to secure a better use of resources, overcome the shortage of craftsmen and obtain greater efficiency and increased output. With the aid of the National Building Agency smaller housing programmes can be pooled with larger ones, in bulk orders for the supply of components or for both supply and erection under a serial contract.

Considerable savings in the cost of housing can also be achieved by local authorities combining in consortia and using industrialised building. A typical example is the North Tyne Housing Consortium, formed by nine local authorities to rationalise the area's municipal housing programme.

There are numerous forms of industrialised building, using vastly differing systems of construction but all based on the common feature of factory-made structural and partition units. Most methods also make extensive use of dry linings and partitions to cut out the difficult 'wet trades'.

Some methods use light steel frameworks, others precast concrete frames and some have introduced timber frames, within which wall, floor and ceiling panels can be fitted. Many systems use concrete or timber framed wall units which can be finished with a variety of coverings and can be made as large as possible, consistent with road transportation limits and ease of handling on site. Roofs may be formed of large panels of various materials or possibly supported on preformed trussed purlins; and prefabricated floor panels are used extensively.

Wall and floor units or panels leave the factory complete with insulation fitted, conduits ready for electrical wiring or water services, door and window frames cast in and painted and windows glazed. When the panels are fitted together on the site, the only jobs usually remaining are hanging of doors, electrical wiring, wall preparing and final painting. Wall cladding is available in a vast variety of colours and textures, and the only plant normally required on the site are mobile cranes. Site labour requirements are often reduced by as much as 25 or 30 per cent and the rate of construction is vastly increased over traditional methods. Traditional forms of construction are often available for external skins of walls and roof coverings.

LAYOUT OF ESTATES

Types of Layout

There are three main types of housing estate layout: the conventional or corridor street layout, use of culs-de-sac and courts and finally Radburn type layouts. Each will now be considered in turn.

(1) Conventional or Corridor Street Layout. In this type of layout most of the houses front onto and have direct access from a development road, and the back gardens to the houses are enclosed. Access to the backs of

houses and enclosed gardens is obtained through side passages, covered ways or stores to houses. The dwellings are sited on either side of a street, separated by their own front gardens, footpaths and carriageway.

Generally, when buildings facing a street are less than half as high as the street is wide the relationship is not entirely satisfactory. Most housing does not conform to the desirable relationship of street width and building height.

(2) **Use of Culs-de-sac and Courts.** The 'garden city' movement introduced culs-de-sac and grouping of houses around grassed areas, and thus produced much more attractive layouts than could be obtained from the use of corridor streets alone. A multiplicity of culs-de-sac, on the other hand, gives the estate a feeling of restlessness, and lengthy culs-de-sac without adequate turning spaces can be very inconvenient.

Houses, 1953 (3) also introduced housing layouts with footpath access to houses, which are sited at right-angles to the road. This type of layout has not very much to commend it, as it is generally inconvenient in use and unattractive in appearance. Fig. 62 show a typical post-war housing estate layout with frontal development, and houses set around courts and approached by footpaths and paved areas.

(3) **Radburn Layouts.** The first form of 'Radburn' layout was used at Radburn, New Jersey, U.S.A. between the wars, and in this layout all main traffic was confined to peripheral roads and road access to houses restricted to culs-de-sac leading in from the traffic route. The houses with their private gardens back onto the culs-de-sac, and front onto communal landscaped areas, through which footpaths give direct access to the schools, shops and amenities without crossing a road. The aim of 'Radburn' layouts, which are now being used extensively throughout this country, is to make safe and separate provision for vehicular traffic and enable many new varied and interesting layouts to be evolved.

Radburn layouts secure complete horizontal separation between pedestrians and vehicles, and also aim at excluding from housing areas vehicles which have no purpose there, by the use of loop roads and culs-de-sac. The choice of route for pedestrian ways should have priority over roads, with regard to directness of route, gradients and intersections with roads. The pedestrian ways should be of sufficient width and be well lit.

At Cumbernauld New Town, the peripheral roads (collector/distributor roads) are 33 ft wide with no footpaths and from these the main culs-de-sac, 18 ft in width, feed into the housing areas with 16 ft wide culs-de-sac leading from them at right-angles. The minor culs-de-sac

serve the garages (1 per dwelling) plus 25 per cent additional parking space in paved areas, fed from the ends of culs-de-sac, for visitors' cars (Hampshire County Council recommends an addition of 50 per cent and the Buchanan report estimates car saturation point in year 2010 at 1.3 cars per family) (17).

In the Cumbernauld development the culs-de-sac have no footpaths, as the routes are intended for estate vehicular traffic only; but unfortunately these roads are used by children with bicycles and prams, and

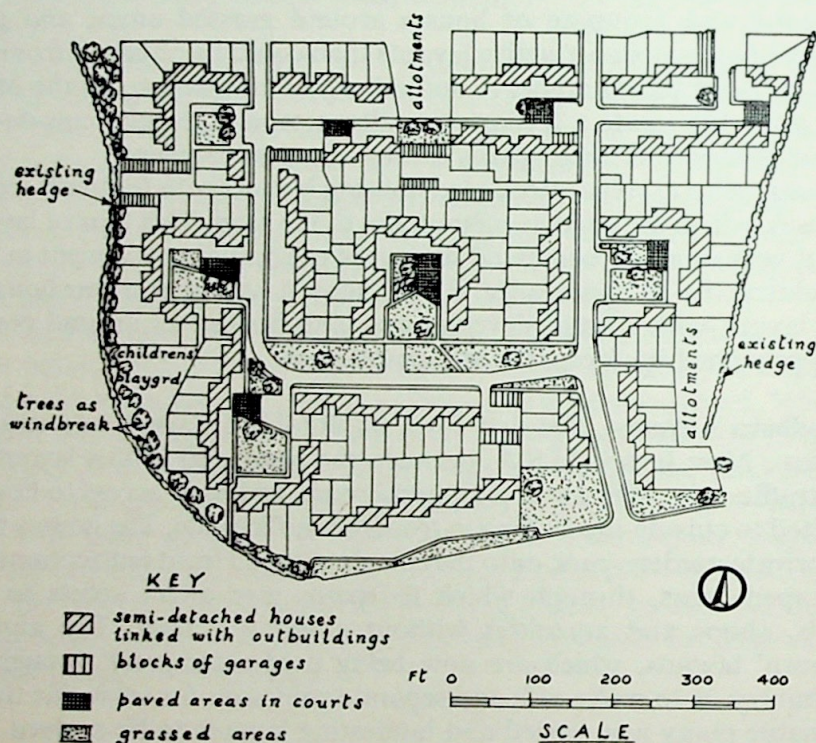


FIG. 62. Typical post-war housing estate layout.

by travelling shops, which generate a considerable amount of pedestrian traffic. Primary pedestrian ways leading from the town centre through the main housing areas at Cumbernauld, are 10 ft 6 in. to 12 ft wide and formed of precast concrete slabs, and so constructed as to take mechanical plant for sweeping and snow clearance without sustaining damage. Secondary or feeder paths are 6 ft to 10 ft 6 in. wide and finished in asphalt, while the local paths laid in front of houses are 6 ft wide and usually of asphalt. Steps are omitted from paths because of the difficulty of negotiation by prams.

Fig. 63 shows part of an estate at Haverhill planned on the Radburn principle, with pedestrian ways passing through covered ways in terraced blocks and through landscaped areas.

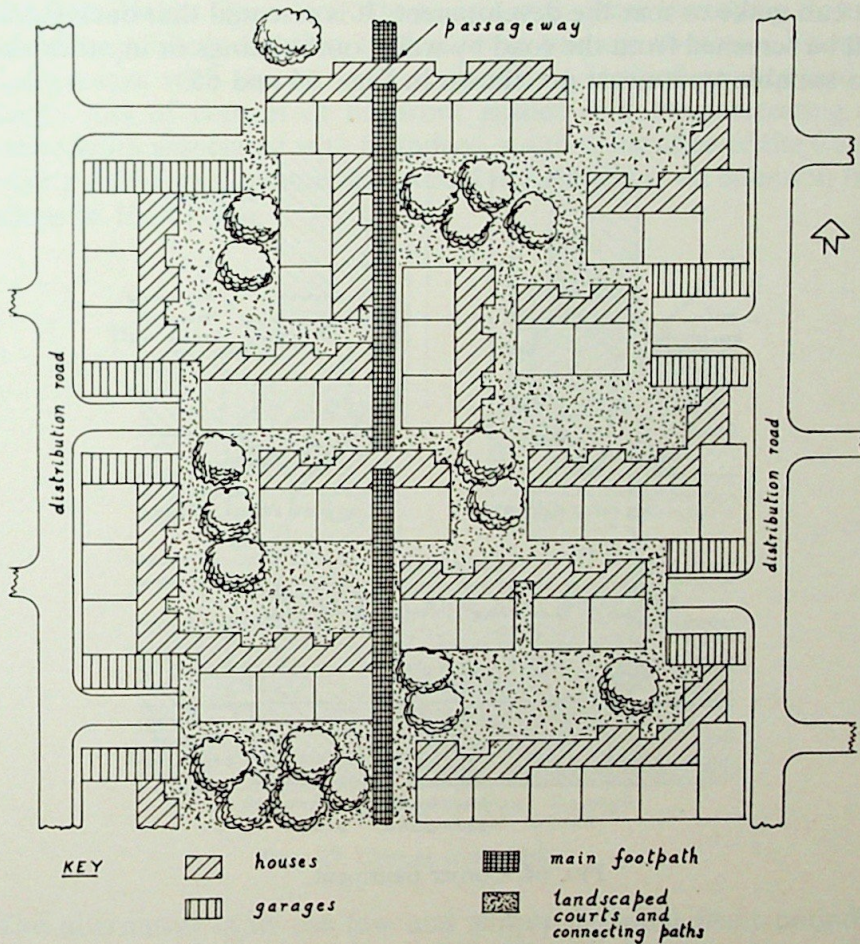


FIG. 63. 'Radburn' layout.

Design Features

Estates can be made very attractive by skilful design and attention to detail. Some of the principal design features will now be considered:

Grouping of Buildings. Very pleasing effects can be obtained by grouping houses around courts and grassed areas, to give added interest and a sense of enclosure. Plate XIV shows an attractive layout of four-storey

maisonettes and timber clad bungalows set in landscaped areas at Cumbernauld New Town.

Corner Treatments. The treatment of corner sites is particularly important as it can make or mar the development. It is essential that back gardens shall be screened from the road by walls, outbuildings or in other ways. Two suitable treatments are shown in Figs. 64 and 65.

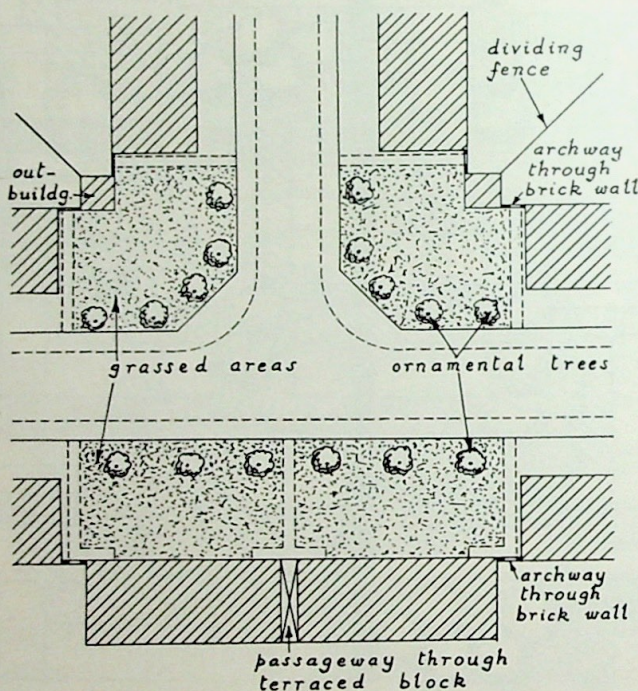


FIG. 64. Corner treatment.

Screening between Houses. The linking of detached and semi-detached houses by garages, outbuildings or screen walls avoids a disjointed appearance and also effectively screens the back gardens.

Sloping Sites. Considerable care is needed when designing layouts on sloping sites. Roads and houses are generally planned to follow the contours as far as possible, as houses and landscape then follow the same line to produce a sense of unity. Where stepping of houses up a site is introduced, it is desirable to make the steps as long as possible, and pairs of semi-detached houses should be treated as a single unit and not broken

into two steps. An attractive appearance is secured by setting the houses on a sloping site at an angle to the road, with each house set back from the next. This is well illustrated on page 9 of *Your House on View* (18).

Front Boundaries. Open fronts to houses with grass stretching from the back of the public footpath to the house can be most attractive. There are disadvantages with this procedure, including lack of privacy and the tenant's loss of control of his front garden and the interesting and creative work associated with it. Indeed, a sub-committee of the Central Housing Advisory Committee reported unfavourably on common front gardens in 1948 (19).

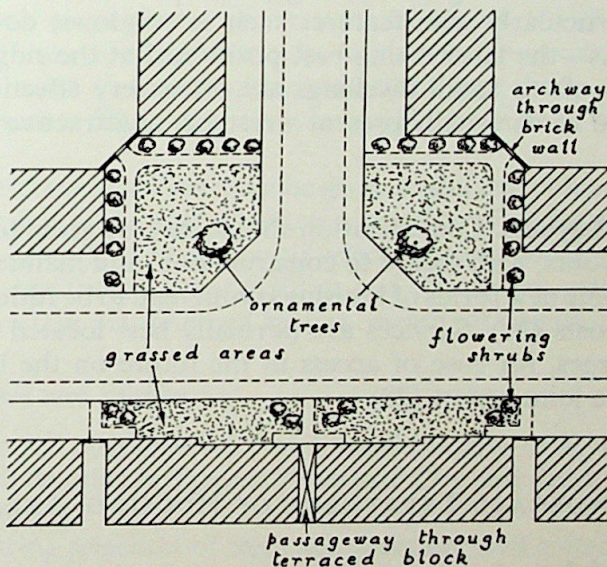


FIG. 65. Corner treatment.

The alternative is to use low and simply designed front boundary walls, hedges or fences. Dwarf brick walls with artificial stone copings and low white painted fences of horizontal rails and posts both look well. Hedges are used far too infrequently, as they can greatly improve the appearance of an estate and permit considerable variety by using different species, such as privet, *lonicera nitida*, hawthorn, hornbeam, beech and myrobalan plum.

Materials of Construction. Special care should be taken in the choice of materials to give suitable colours and textures. Local materials usually look attractive and weather well (20). Brightly coloured bricks should

never be used in a stone district, and it is desirable to use roof tiles or slates of a darker colour than the wall facing material. Careful choice of painting colours is also needed—generally white frames to doors and windows and bright coloured doors look well. Pairs of semi-detached houses and all the dwellings in a terraced block are best painted in the same colours, to form a single unit in design (18).

House Types. The most attractive layouts are obtained when extensive use of terraced blocks is adopted. The longer horizontal lines give a feeling of repose, which is unobtainable with smaller units. Too many bungalows and detached houses resemble boxes topped by a pyramid and care is needed in design to secure good proportions and simplicity of treatment, particularly with features such as windows, doorways and chimney stacks—the latter being best positioned at the ridge. Flat and low pitched roofs to small dwellings are often very effective, whereas rows of hipped roofs usually present a restless, unattractive appearance (18).

Economics of Layouts. Consideration should also be given to the cost of alternative layouts, with regard to constructional and maintenance costs of services. Some new forms of housing layout tend to be rather expensive in servicing costs (21). Services are normally best located under foot-paths and verges, for ease of access in the future on the lines recommended in the joint report (28).

LANDSCAPE TREATMENT OF HOUSING AREAS

Guiding Principles

The planting of trees and shrubs on a housing estate can do much to improve the overall appearance of the estate. Trees take many years to grow and so existing trees, which are in good condition, should be preserved if at all possible. Furthermore, existing trees, shrubs and plants give a good indication of what new species are likely to thrive as far as climate and soil are concerned.

There is rarely sufficient space on housing estates for forest type trees, but smaller trees such as whitebeam and mountain ash, as well as many types of flowering tree, can be used to advantage. Trees can be planted singly or in clumps, on grassed verges, larger public open spaces or in front gardens reasonably close to the front boundaries. It has been suggested that local authorities should sell trees, shrubs and plants to

tenants from their nurseries, and many local authorities seek to encourage the interest of tenants in gardening by organising annual garden competitions and awarding prizes and cups (19).

Trees generally have great value in form as well as colour, and they should be chosen to blend the architecture and landscape into a single composition. They change with the season and give a living quality to the hard surfaces, and angular shapes of buildings and roads. In summer, trees in leaf have great beauty in both form and colour, and in winter the silhouette and shadow of branches and twigs provide fascinating decoration to nearby walls.

The irregular shapes and siting of trees can often be used deliberately as a contrast to architectural regularity. In some cases the vertical forms of trees, such as poplars, can be used to contrast with the long low horizontal forms of terraced blocks of houses. Trees are also useful as a barrier to noise and headlight glare and to give shade and serenity in the urban scene. They can also form shelter belts in windy exposed situations.

In all cases, consideration must be given to soil and climatic conditions, the ultimate size of the suggested trees, location of underground services and nearby houses, with a view to selecting trees which will not cause problems in the future. *Trees in Town and City* shows with illustrations how effective tree planting can be in a variety of situations (22).

Suitable Trees and Shrubs

The principal characteristics and requirements of a wide range of trees are well detailed in *Trees in Town and City* and *Trees for Town and Country* (23).

The following selection of trees are generally well suited for planting on housing estates:

Type	Height	Flowering Season
Prunus Fugenzo (cherry)	30 ft	May
Pyrus Malus Lemoinei (flowering crab—crimson, with purple leaves)	30 ft	April
Laburnum Alpinum (yellow)	25 ft	June
Pyrus Malus Purpurea (crab—pink, with purple leaves)	30 ft	April
Pyrus Malus Eleyi (flowering crab—red)	30 ft	May
Sorbus Aucuparia Piscolor (mountain ash) (red berries)	35 ft	—
Crataegus Oxyplena Coccinea (double scarlet)	20 ft	May
Crataegus Oxyplena Alba (white)	25 ft	May
Prunus Sargentii (single pink)	25 ft	Autumn
Prunus Communis (almond—pink)	20 ft	Feb. to April

A wide variety of shrubs are available of which some of the more common are now listed:

<i>Type</i>	<i>Height</i>	<i>Flowering Season</i>
Berberis Wilsonii (red berries)	2 to 4 ft	Spring
Berberis Darwinii (orange flowers, blue berries)	6 to 8 ft	Spring
Berberis Thunbergii (yellow flowers, red berries)	3 to 5 ft	Spring
Berberis Stenophylla (yellow flowers, bluish-white berries)	5 to 6 ft	Spring
Buddleia Alternifolia (mauve flowers)	4 to 6 ft	Summer
Spiraea Japonica Bumalda (red flowers)	2 ft	Summer and Autumn
Cytisus (broom) (yellow flowers)	4 to 5 ft	Spring
Cotoneaster Horizontalis (pink flowers, scarlet berries)	2 to 4 ft	Spring

Planting of Trees and Shrubs

It is essential that all trees purchased should come from a reputable nurseryman and should be good, well-grown trees, which have been moved within two years in the nursery and have plenty of fibrous roots. Small trees require holes about 5 ft in diameter and where there is little topsoil and the subsoil consists of chalk, clay or poor quality sand, the hole should be filled with topsoil, and the addition of manure or leaf mould around the roots is well worthwhile. In all cases there should be a good layer of topsoil at the reinstated surface. Where the ground is moist and drainage poor, it is good practice to lay some brick rubble or clinker at the bottom of the hole.

Deciduous trees and shrubs can generally be planted from the end of October to the middle of March; November and December being the best months if weather conditions are suitable. In heavier soils and colder parts of the country, spring planting is preferable. Evergreens may be planted in the spring or during the autumn if the soil is moist.

Trees, should be planted as soon after arrival as possible, except in frosty weather. On planting the topmost roots should be about 3 in. below the surface, and the mark on the stem showing the position of the earth surface in the nursery is a useful guide as to depth of planting. The roots should be well spread out and soil made firm around the roots by gentle treading. It is advisable to protect young trees with stakes and guards.

After planting, the soil around trees must be kept weeded and young trees and shrubs should be watered and mulched with manure or grass cuttings if a dry spring or summer follows planting. Frequent attention must be given to the ties which hold the trees to stakes. Infrequent light

pruning may also be needed, and if large branches are removed the cut should be flush with the junction of the trunk or other branch and be dressed with bituminous preparation.

Further information on planting and pruning of trees can be obtained from publications (24) and (25).

HOUSING MAINTENANCE

Costs

Housing maintenance work involves local authorities in vast expenditure and house designs should be carefully considered with a view to reducing subsequent maintenance costs. Far too little attention is generally paid to the relation between initial capital costs and subsequent running and maintenance costs, the latter being collectively termed 'costs in use'. The constant feed-back of information from the user to the designer would help considerably in this connection, with the object of reducing future maintenance work at the design stage.

One large authority analysed the cause of maintenance costs with the following results:

Fair wear and tear	56.0%
Frost damage	1.5%
Faulty materials and workmanship	12.5%
Design or specification faults	20.0%
Miscellaneous repairs	0.5%
Work carried out unnecessarily	4.0%
Damage by tenant and chargeable to him	5.5%
Total	<u>100.0%</u>

This breakdown indicates a great need for more care in design and greater regard to future maintenance work.

Actual maintenance costs vary appreciably in different parts of the country and between different types of dwelling. For instance, in 1959/60 the average total annual maintenance cost of pre-war dwellings ranged from £15.10.0 per dwelling in the North of England to £27.5.0. in London, and post-war dwellings ranged from £7.11.0 to £15.18.0 (27). The heaviest single class of expenditure is usually plumbing work, followed by carpentry and joinery items, but fireplaces, external repairs to brick-work and paths and fencing repairs are also costly maintenance items. The cost of maintaining pre-1930 houses can be 2 to 3 times as high as

post-war houses and, in general, maintenance expenditure increases with the age of the house at the rate of about 7s. to 8s. per year.

Organisation of Work

From questionnaires sent out by the Institution of Municipal Engineers in 1952, it was found that in the majority of authorities serving areas with populations in excess of 100,000, housing maintenance work was the responsibility of the housing manager, whereas in smaller authorities it was generally under the control of the engineer. Approximately 70 per cent of the work was carried out by direct labour, 10 per cent by contract and the remaining 20 per cent by a combination of both.

The principal method of reporting repairs is through rent collectors, although some come by post, telephone calls and visits to offices, apart from those picked up by inspections. Where the card system of reporting repairs is operated, it is important that the tenant is asked to indicate times when the house is occupied, to reduce the number of visits by operatives to empty houses. Most authorities issue job tickets in duplicate or triplicate, a copy of which is used by the operative on the job and returned with his time sheet, etc. Details of work performed is normally recorded on house cards in the office. The records must permit a constant check to be kept on outstanding work and to show which types of house and fittings involve heaviest maintenance costs. They will also indicate the more careless tenants.

External painting is generally carried out by the local authority at about 5-yearly intervals, the first painting taking place within 2 to 3 years of occupation. Some adjustment may be necessary in rural areas to combine houses in an isolated village for painting purposes. An average output is one man per week per house for external painting.

Tenants are generally responsible for internal decorations and repairs resulting from wilful damage, negligence and for broken windows. Some authorities supply decorative materials to tenants for internal use (26).

It is generally agreed that a thorough inspection of all local authority dwellings should be carried out at intervals of 3 to 5 years, and some authorities have introduced planned maintenance schemes, whereby groups of houses, in accordance with their design and age, are inspected and scheduled for repair and maintenance at about 4-yearly intervals. The work found necessary is costed and approved and a temporary base established with supervisors, operatives and stores. The back-log of maintenance work is removed and maintenance costs reduced. Further savings can be obtained by bulk purchasing of materials and components.

Authorities owning large housing estates may find it advantageous to establish sub-depots and possibly rent collection and enquiry offices on each estate or group of estates. While in large rural districts tradesmen need vehicles for transportation from one village to another, and 8 and 10-cwt vans seem to be the most popular for this purpose.

Good timekeeping is essential and all operatives should be required to report at a depot morning and evening. Similarly, constant supervision is needed and the operation of incentive bonus schemes may be considered as a means of increasing output. Some flexibility of working is needed with most tradesmen, to occasionally cover work which is not strictly within their trade, and skimping of work or use of inferior materials must be prevented as it can only lead to further trouble.

It is good policy to issue all tenants with tenants' handbooks giving information on housing regulations, the use of fittings and local amenities. Strict control of garden sheds, keeping of poultry and upkeep of gardens should be enforced in the interests of tenants at large.

Modernisation of Pre-war Houses

Many pre-war local authority houses are lacking in proper bathrooms and hot water supply systems, and frequently the only W.C. in the house is entered from outside the house. In recent years many of these houses have been modernised with the provision of modern bathrooms, internal W.C.s and efficient hot water supply systems.

Basically, there are three main methods of approach:

- (1) Internal rearrangement on the ground floor to provide a bathroom and W.C., if sufficient space is available.
- (2) Conversion of the third bedroom into a bathroom; this is probably the cheapest method but reduces the amount of accommodation. Even where a house is under-occupied, the third bedroom is useful in times of sickness and for use by visitors.
- (2) Conversion of a store adjoining the house, which, because it is built of 4½ in. brick walls, often necessitates the provision of an additional 3 in. inner skin or 4½ in. outer skin, according to the size of the structure.

The hot water supply may be obtained by means of a back boiler behind a living-room fire, with an immersion heater for summer use, or the installation of suitable electric or gas water heaters. Old appliances, such as shallow sinks, are replaced with new fittings and it is usually necessary to rewire the dwelling. In 1965 costs ranged from £250 to £550 per dwelling, depending on the work involved.

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CHAPTER TWELVE

Other Services

THE municipal engineer is expected to advise his authority on the provision and maintenance of a variety of different services, apart from those listed in earlier chapters of this book. These further services include parks, playing fields, children's playgrounds, allotments, cemeteries and crematoria, swimming baths, public conveniences, shelters, depots, markets, municipal offices and even, on occasions, airports. Some of the main features in the design and construction of these various services will now be considered.

PARKS, PARKWAYS AND GARDENS

Parks, parkways and gardens possess tremendous amenity value and bring fresh air and greenery into a town or city. Parks and public gardens provide space for open-air enjoyment, rest and relaxation, and require skilful design and a high standard of maintenance to achieve the best results. The provision of raised and sunken gardens, possibly incorporating pools of water and fountains and connected by paths and steps, often form the basis of the layout. Extensive grassed areas with avenues or clumps of trees and shrubs can be used to advantage where sufficient space is available.

Great care is needed in the selection of suitable trees and shrubs, having regard to soil and climatic conditions, ultimate height and girth and flowering season. When forming a shrubbery, smaller shrubs, often 2 to 3 ft high, should be planted in the front row with subsequent rows of shrubs of increasing height, rising to probably 12 to 15 ft high in the back row of a border shrubbery or centre of an island shrubbery, so that all shrubs are seen to advantage. It also good policy to secure a

selection of shrubs with differing flowering seasons to give a display of colour over a long period. The provision of some evergreen shrubs and others with coloured berries in the autumn and winter will help to take off some of the bleakness of the winter scene.

In large parks, forest type trees such as oak and horse chestnut, can be provided to give beauty of form and shade. Ample seating accommodation should always be provided; teak seats being the most attractive and popular but also the most expensive. Litter bins need to be provided in the vicinity of seats, of which the wooden slatted variety blend in extremely well with their surroundings.

The central garden for the blind provided at Plymouth deserves special mention, with sweet-smelling plants such as mignonette, candytuft marigold, verbena and pansies in beds at a height of about 3 ft, behind the perimeter wall which surrounds the garden. On the sloping coping stone of the perimeter wall, metal plates have been fixed with plant names in both Braille lettering and raised block lettering, so that both blind and sighted persons can identify the flowers.

The parks department in a large town normally propagates its own plants and shrubs for use in parks and gardens, and for floral displays. It is generally found that the most economical arrangement is to centralise these facilities in one unit with glasshouses, potting shed, mess room and stores. Glasshouses are often constructed of aluminium alloy framing supported on dwarf brick walls and heated with oil-fired boilers and hot-water pipes.

PLAYING FIELDS

The generally accepted national standard for the provision of public playing fields (excluding school playing fields and full-length golf courses) is 6 acres per 1,000 population. On a reasonably shaped site, 6 acres could accommodate a senior football pitch, 1 junior football or hockey pitch, 1 cricket table, 2 netball courts, a 3-rink bowling green, 2 tennis courts, a children's playground of about $\frac{1}{2}$ acre in extent and a pavilion, as illustrated in Fig. 66. Extensive information on the requirements and layout of playing fields can be obtained from the book listed in reference 1 at the end of this chapter.

Layout of Playing Fields

The grouping of playing pitches greatly assists maintenance work, and much space can be saved by siting pitches for winter sports on cricket

outfields. The best orientation for playing pitches is approximately north to south.

Pavilions should be sited to provide a clear view of both ends of the cricket table and to avoid aspects from south-west to north-west. Pavilions, tennis courts, bowling greens and children's playgrounds are

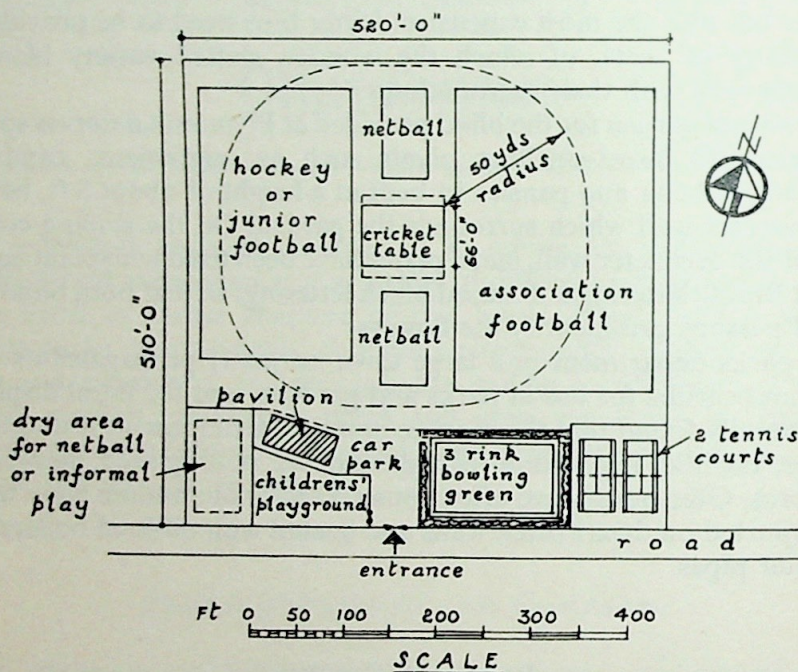


FIG. 66. Playing field layout.

best sited reasonably close to the access road, to limit the length of footpaths and services. The children's playground should be enclosed and preferably have its own access from the access road.

Pitch Sizes

The following table lists the dimensions of the various types of pitch with the clearances required around them. Where pitches are adjacent to the boundaries of the ground it is desirable to increase the marginal clearances by 10 ft.

TABLE 13. SIZES OF PLAYING PITCHES

Game	Play group	Length of pitch	Width of pitch	Marginal clearances	
				sides	ends
Association Football	Seniors	105 to 110 yd	65 to 70 yd	20 ft	30 ft
	Juniors	100 yd	50 to 60 yd	20 ft	30 ft
Rugby Football	Seniors	105 to 110 yd	70 to 75 yd	20 ft	20 ft
	Juniors	100 to 105 yd	65 to 70 yd	20 ft	20 ft
Hockey	Men	100 yd	55 to 60 yd	10 ft	15 ft
	Women	90 to 100 yd	55 to 60 yd	10 ft	15 ft
	Juniors	90 yd	55 yd	10 ft	15 ft
Netball	All groups	100 ft	50 ft	6 ft (increased to 10 ft where adjoining another court or boundary)	6 ft
Tennis	All groups	114 ft	56 ft	Each additional court in same enclosure will be 46 ft wide. A side- shifting allowance of 23 ft should be included for each grass court.	
Bowling Green (6-rink)	Adults	126 ft	126 ft	17 ft (to allow for ditch, footpath and external bank)	17 ft
Running Track (4 laps to 1 mile)	All groups	602 ft	242 ft 10 in.	Allowing for 27 ft wide track and 120 yd long parallels	
Cricket	Cricket table should be 90 ft × 90 ft where possible. Boundary of outfield is 50 yd radius from intersection of bowling crease and edge of table for seniors and 40 yd radius for juniors.				

Construction of Playing Fields

Details of construction of playing pitches, cricket tables, hard tennis courts, bowling greens and running tracks will now be given. Detailed specifications for these jobs can be found in the National Playing Fields Association publication (2).

Playing Pitches. The site must be cleared of all rubbish and large stones, broken up with a suitable plough, cultivator or harrow and graded (no gradients should exceed 1 in 50). The whole of the site must have a minimum covering of 4 in. of vegetable soil, rolled with suitable agricultural rollers to give a firm even surface free from local undulations.

Where under-drainage is necessary, porous concrete or clayware land drains are normally laid in herring-bone fashion under the site, the main drains often being 4 in. to 6 in. in diameter and the branch drains up to 100 yd in length of 3 in. diameter and laid to gradients as flat as 1 in 200, with a minimum depth to invert of 1 ft 6 in. The spacing of the drains varies with the type of soil, from 12 ft in very heavy soil to 60 ft in a very light soil. The upper part of each joint is protected with waterproof paper, or other suitable material, to prevent fine material entering the pipes during backfilling. The drain trenches are sometimes partially backfilled with clinker, broken stone or shingle. Catchpits on the main drains usually have their bottoms 12 in. below the inverts of the pipes.

The ground should be dressed with Fish Guano or other approved grassland fertiliser, at the rate of 5 cwt per acre, applied in two equal sowings of $2\frac{1}{2}$ cwt each at right angles to one another. At least 7 days after fertilising, the ground can be seeded down at the rate of 2 cwt per acre, applied in two equal sowings of 1 cwt each with a broadcast machine. The grass seeds are lightly harrowed in and the surface is lightly rolled.

A suitable grass seed mixture for this class of work is:

- 60% Short seeded perennial rye grass
- 20% Chewings fescue
- 10% *Poa pratensis* (smooth stalked meadow grass)
- 10% New Zealand crested dogstail.

It is usual to provide for a further application of fertiliser during the maintenance period (preferably 6 months with spring sowing and 9 months with autumn sowing). Maintenance of grassed areas comprises weekly cuts from mid-March to early October, spiking, rolling in the spring and periodic applications of fertiliser and selective weed-killers.

A wealth of information on the construction and maintenance of school playing fields is contained in Building Bulletin 28 (15).

Cricket Tables are generally turfed, when the operations consist of grading and rolling the site and top dressing with bone meal at the rate of 4 oz per yd², which is lightly raked. Suitable turf cut square and boxed to a uniform thickness of $1\frac{1}{4}$ in. is packed, as required, with sifted soil and lightly consolidated with a turfing mallet. Each turf should be hand

weeded to remove all visible weeds before being laid. The turfed area is then top dressed with sifted soil, care being taken to work the soil well into the joints.

Hard Tennis Courts. The site is stripped of vegetable soil and graded to a crossfall of between 1 in 60 and 1 in 120. Under-drains are laid in herring-bone pattern to a main drain running diagonally across the courts, discharging into a ditch, surface water drain or soakaway. The formation should be treated with sodium chlorate solution (1 lb to 1 gal of water), at the rate of 1 gal per 10 yd² of surface to prevent weed growth.

Edging to tennis courts can be formed in class 'B' engineering bricks or precast concrete edging. The foundation to the courts can be 4½ in. consolidated clinker, graded 3 in. to ¾ in., blinded with a 1 in. layer of ash. The surfacing should be bituminous or tarred limestone of 2 in. consolidated thickness, applied in 2 layers (1½ in. base course, 1 in. to ¾ in. gauge and ½ in. wearing course, ¼ in. to ⅛ in. gauge). After weathering the surface is usually sprayed with two coats of green tennis court composition.

The tennis court enclosure is normally constructed of 1½ in. mesh 14 gauge plastic coated chain link fencing, 9 ft high, tied to 4 rows of 8 gauge straining wires, attached to 2½ in. × 2½ in. × ¼ in. angle steel corner and gate posts (set 2 ft 6 in. into the ground and strutted and concreted) and 1½ in. × 1½ in. × ¼ in. angle steel intermediates (driven 2 ft into the ground) at 10-ft centres. Gates are provided as necessary.

Bowling Greens. The site is levelled, covered with vegetable soil and the formation treated with colloidal lead arsenate solution (2 lb to 1 gal of water) at the rate of 1 gal per 25 yd², or other suitable preparation, to prevent worms and other pests working through the green. Under-drainage is normally provided as described for tennis courts.

Ditches, 12 in. wide, are formed round all four sides of the green with sides of creosoted boarding or precast concrete edging. The ditches are normally filled with clinker topped with round beach pebbles (1½ in. to ¾ in. gauge), finishing 1½ in. below the level of the green. Sea washed Cumberland turf is frequently used for bowling greens, laid on a 6 in. clinker foundation, blinded with fine ash. The turf is usually cut in 12-in. squares, 1¼ in. thick, laid in diagonal courses and bedded on a compost of sand and fertiliser. Where the green is surrounded by a wall instead of a turfed bank, it is necessary to plug creosoted timber slats or battens to the face of the wall, to prevent damage to woods.

Running Track. The site is excavated to a uniform level and rolled. Under-drainage is provided by laying agricultural land tile drains just

inside each edge of the track. Precast concrete edging (6 in. $\times$ 2 in.) is often laid to the edges of the track, finishing 2 in. above finished track level.

The excavation should be treated with sodium chlorate solution to prevent weed growth, and in it a foundation of clinker of 8 in. consolidated depth is laid in two layers (3 in. to $\frac{3}{4}$ in. gauge, $4\frac{1}{2}$ in. thick and $\frac{3}{4}$ in. to $\frac{1}{2}$ in. gauge, $3\frac{1}{2}$ in. thick) and rolled with a 5-cwt roller.

Various alternative processes are available for the final stages; one popular method is to apply two courses of a mixture of fine clinker ash, riddled clay or marl and fine washed sand, which are watered, brushed and rolled with a 15-cwt roller (bottom course mix of 1 part ash, 4 parts clay and $2\frac{1}{2}$ parts sand, mechanically mixed, 3 in. thick, and top course 1:2:1 mix, 1 in. thick). Finally, the surface of the track is sprayed with sodium chlorate solution.

SPORTS CENTRES

Some of the larger towns have provided sports centres, incorporating stadiums for athletic use. Britain's first national sports centre, provided by the former London County Council, was opened in 1964 at Crystal Palace (estimated cost £12 million). This centre provides extensive facilities for amateur practice, training and competition in a wide range of sports. The three principal features are a sports hall, stadium and residential hostel. There are also concert facilities, a rock and water garden, children's zoo, boating and fishing lake and extensive car parking accommodation adjoining the site.

The sports hall consists of a reinforced concrete structure with 100 ft steel roof trusses, and is 284 ft $\times$ 266 ft $\times$ 70 ft high. It contains the main indoor training and instruction facilities, a swimming hall with three pools, general changing rooms and seating for spectators.

The stadium is partially excavated from the hillside and has accommodation for 12,000 spectators. A saddle-shaped stand can accommodate 4,000 spectators under cover, facing east-north-east to protect them from sun glare. The seating is constructed of reinforced concrete.

The hostel provides residential accommodation for up to 138 visitors, together with dining rooms and recreational facilities.

CHILDREN'S PLAYGROUNDS

It is essential that adequate provision should be made for children's playgrounds, to prevent children having to play in the street. In recent

years the pattern of children's playgrounds has changed somewhat with the introduction of 'adventure playgrounds'.

Space Requirements

The National Playing Fields Association recommends a minimum provision of 40 ft² per child, with an additional 15 ft² per child where provision is made for paddling pools, sand pits, roller skating, etc. It is generally found that areas under $\frac{1}{4}$ acre are rarely satisfactory for this purpose.

TABLE 14. TYPES OF PLAYGROUND EQUIPMENT

<i>Type of equipment</i>	<i>Safety clearance dimensions</i>
Swings	
8 ft high, cradle seats, set of 3	21 ft × 21 ft
8 ft high, cradle seats, set of 6	30 ft × 21 ft
10 ft high, normal seats, set of 3	21 ft × 30 ft
10 ft high, normal seats, set of 6	33 ft × 30 ft
Merry-go-round	22 ft diameter
Ocean Wave	24 ft diameter
Plank Swing	
small size	30 ft × 17 ft
large size	42 ft × 18 ft
Slide:	
30 ft long	48 ft × 7 ft
40 ft long	58 ft × 7 ft
50 ft long	70 ft × 8 ft
Rocking Boat	21 ft × 9 ft
Rocking Horse	18 ft × 9 ft
See-saw	18 ft × 4 ft
Horizontal bars set of 3 (4 ft, 5 ft 6 in. and 6 ft high)	25 ft × 12 ft

Layout of Playgrounds

It is advisable to group all the items of playground equipment together on a paved surface, preferably finished in asphalt. Intervening grassed areas soon become muddy patches and are best avoided. It is desirable to allow 10 ft wide margins between the safety clearance areas for

equipment, recommended by the manufacturers, and 5-ft margins alongside boundaries. This arrangement also permits the maximum use of available space, simplifies management and supervision, causes less restriction on the movement of children and enables the equipment to be used at all times of the year.

It is good practice to enclose the playground with a hedge or border of trees and shrubs, to form an attractive background and provide a

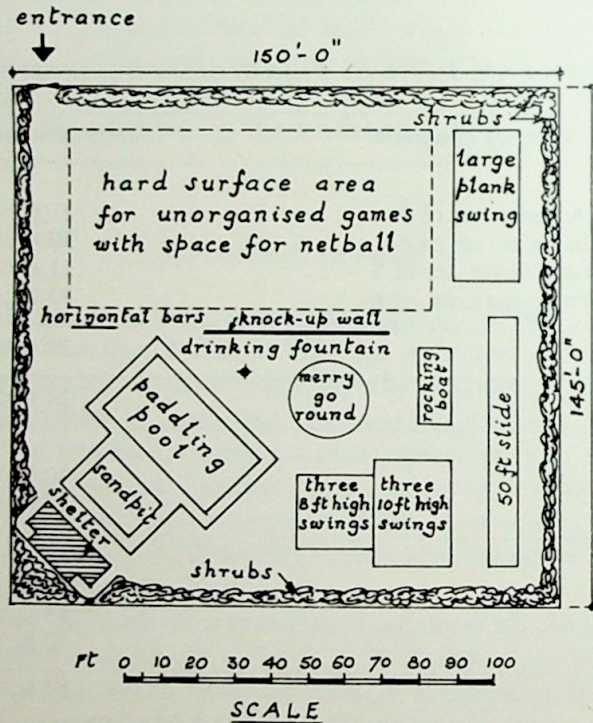


FIG. 67. Layout of children's playground.

windbreak and shade. Recessed gateways sited to face the nearside traffic, with self-closing gates opening inwards and barriers erected on the kerb are helpful from the safety aspect. The provision of a hard surface area for unorganised games is extremely useful for hop-scotch, roller skating, scooters, etc., in all weathers. Similarly, knock-up walls can be used for a variety of ball games.

As to choice of equipment, the author has found over a period of years that horizontal bars form one of the most popular items of play-

ground equipment, but they are one which is often omitted. Swings, slides, merry-go-rounds and plank swings are other popular features. Sandpits are welcomed by the younger children but provision must be made for periodic changing of the sand. Cradle type swings are invaluable when catering for children in the 2 to 5 years age group, although they are sometimes subject to misuse by older children.

All equipment should be inspected, oiled and greased at monthly intervals. Fig. 67 shows a suitable layout for a children's playground on a $\frac{1}{2}$ acre site.

Adventure Playgrounds, etc.

In more recent years, various types of adventure playground have been introduced, substituting concrete pipes, timber logs, earth mounds, etc. for the more orthodox items of equipment. Some local authorities have gone much further in this respect, for instance, Camden Borough Council opened an exciting community play centre in 1965, occupying $2\frac{1}{2}$ acres and costing about £24,000.

The outdoor facilities include a roadway system complete with traffic lights, international signs, zebra crossings and a tunnel, a garage, housing estate with houses about 6 ft high, shops and a town hall. There is also a workshop for the maintenance of cars and bikes supplied by the council or owned by the children, and a floodlit football/netball pitch (five a side). There are indoor facilities for painting, modelling, sewing, cooking and playing chess and other games, with a wide range of equipment and indoor sand and water play facilities. All age groups have been catered for and there are special features for 'under fives'.

The publication *Homes for Today and Tomorrow* (3) gives some useful suggestions on the design of playspaces, in connection with high density schemes of residential development. For children 2 to 5 years of age, suggested items include paved areas (for tricycles, dolls' prams and push and pull toys), low walls and steps (for balancing and jumping), rough ground (for digging), sand box or sand pit, low water tray (for sailing boats and playing with water toys), low weatherproof fixed tables and chairs and a shelter (open on two sides). For 5 to 11-year-old children, suggested features include climbing frames, rough ground, fixed logs, play sculpture, fixed table and benches, concrete equipment (shaped as boats, forts, etc.) and an enclosed area for ball games. Where supervision is possible further and more imaginative items can be provided such as wigwam tents, Wendy houses, table games, easels for painting and clay for modelling.

ALLOTMENTS

The demand for allotments is on the decline and suitable provision would probably be in the order of $\frac{1}{2}$ acre per 1,000 population, as proposed for Hook. Care is needed in the selection of sites to ensure that the soil is of reasonable quality, well-drained and suitably terraced on sloping sites, and that they are conveniently situated in relation to the main residential areas.

Allotment sites need to be suitably enclosed, 5 ft high chain link fencing often being used for this purpose, but hedges preferably of quick-thorn, beech or hornbeam, are far more attractive and provide a much

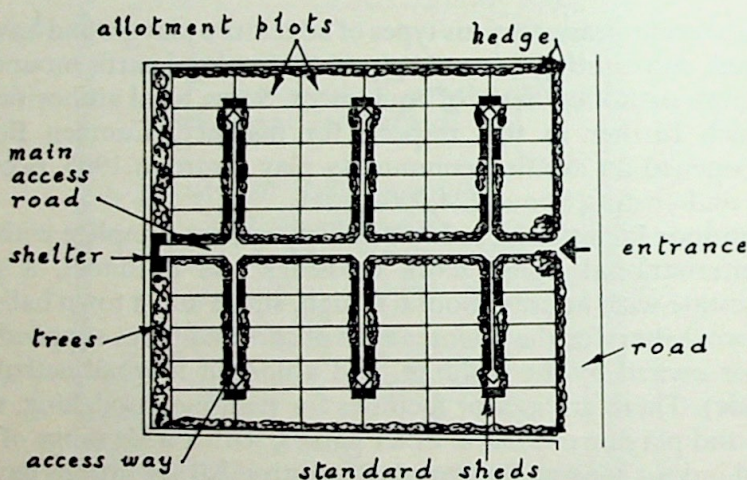


FIG. 68. Layout of allotments.

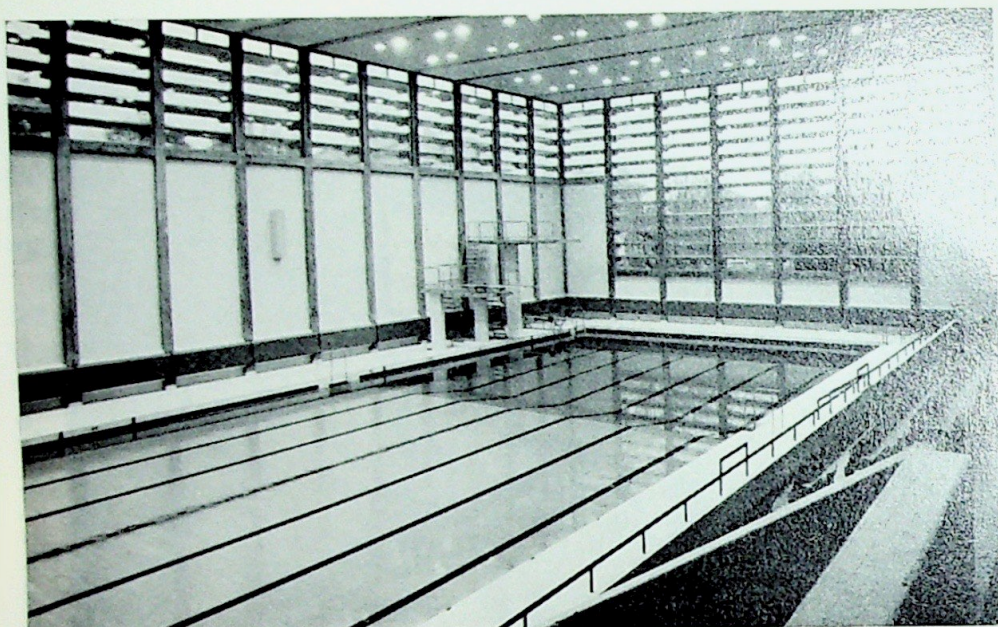
better screen. Main access roads through the allotments are normally about 10 ft wide with narrow paths separating the allotment plots, which are generally 10 rods in area. The access roads can conveniently be surfaced with hoggin, but the paths are usually left unsurfaced.

Water services should be laid on to allotments sites with standpipes discharging through bib-taps, often over storage tanks of about 60 gal capacity, spaced about 50 yd apart along the access roads. Stopcocks and draining-off cocks should be provided at the feet of standpipes for draining off the water in the winter.

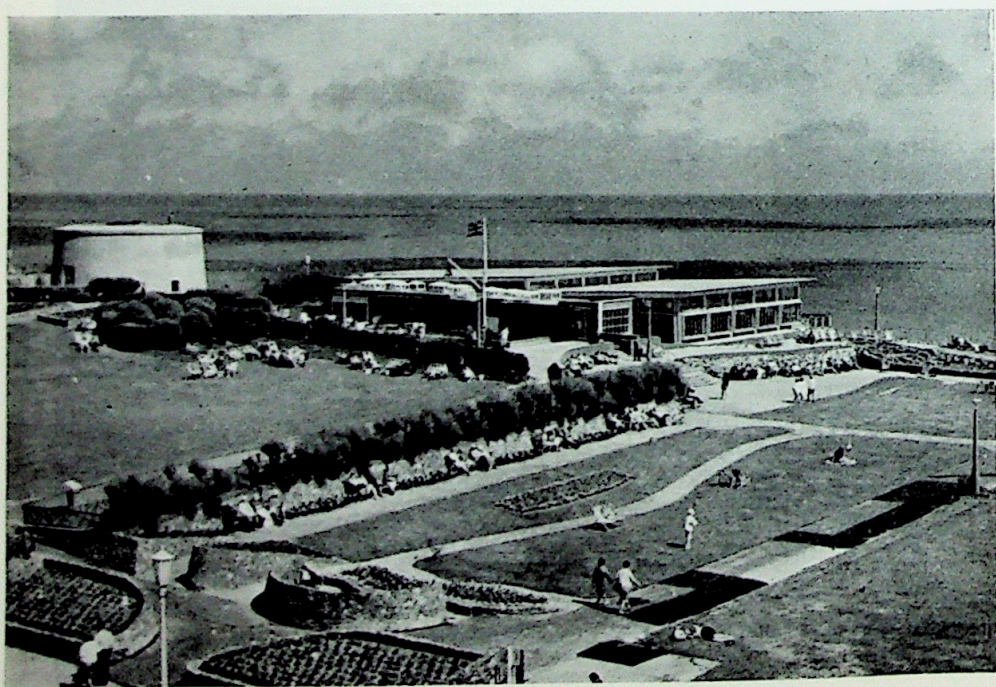
Allotments can be made much more attractive than is usual by judicious hedge planting and the erection of standard sheds. Fig. 68 illustrates a layout of allotments designed with this theme in mind.



XIV Mixed Development, Cumbernauld New Town



XV Swimming Bath, Hampstead



XVI Wish Tower and Sun Lounge, Eastbourne

CEMETERIES

The siting requirements of cemeteries are listed in Chapter X. Their layout normally proceeds on rectangular lines to accommodate the maximum number of grave spaces, often 8 ft × 3 ft 6 in. in size. Access roads are provided of varying widths and for which the most common form of construction is tarmacadam or asphalt with precast concrete edging. Water standpipes and litter receptacles for dead flowers are essential features.

Cemeteries are probably best enclosed with beech or hornbeam hedges and should be planted with carefully chosen and sited trees and shrubs. A high standard of maintenance is essential, taking care not to omit those grave spaces for which the local authority has assumed responsibility, such as war graves.

SWIMMING BATHS

There is an increasing demand throughout the country for swimming baths, but unfortunately these are one of the first items to be postponed during periods of financial stringency. Indoor pools can be used under all weather conditions, while outdoor pools with extensive sunbathing areas can prove most popular in warm periods. There is also a very large demand for children's pools.

Design of Pools

Swimming pools can often be advantageously combined with gardens and playing fields to form a sports and recreation centre, where games of all kinds, water and sun bathing, refreshment and rest are available to all sections of the community. Adequate car and cycle parking space should be provided near any swimming bath (4).

Various shapes of pool are in use—rectangular, wide rectangular and oval or elliptical, of which the rectangular is the most common. Pools are normally constructed of reinforced concrete and the design and construction should be in accordance with CP 2007 (5).

There are four basic types of swimming pool: teaching, competitive swimming, diving and children's, the requirements of each being fully detailed in the Ministry publication on Swimming Pools (6).

(1) **Teaching Pools.** Suggested lengths vary from 41 ft 3 in. to 82 ft 6 in. (multiples of 110 yd) and widths from 24 to 30 ft (multiples of 6 ft lanes).

The depth at the shallow end is 3 ft and the maximum depth at the deep end ranges from 5 ft 6 in. to 11 ft 6 in.

(2) **Competitive Swimming Pools.** The majority of larger local authorities provide main pools 110 ft $\times$ 42 ft, although 165 ft $\times$ 56 ft is needed for international events. Where provision for diving is made in the pool, it is advisable to construct a separate diving pit, a diving bay off the side of the main pool, or a boom or other device to separate the swimming and diving areas.

(3) **Diving Pools.** The dimensions of diving pools are determined by the height and number of diving stages. The main types of diving board being 1 and 3 metre springboards and 5, 7½ and 10 metre fixed boards (the dimensions in metres refer to the height above the water of the diving board and one metre = 3 ft 3½ in. approx.). The Ministry publication (6) includes a schedule giving full dimensions relating to each type of diving board (water depths range from 9 ft 10½ in. to 14 ft 9½ in.).

(4) **Children's Pools.** There is usually a heavy demand for pools to accommodate children and toddlers and it is good policy to make separate provision for them. It is recommended that these pools should not exceed 600 ft² in area with a depth of 1 ft to 1 ft 6 in. with walk-in access steps along the entire length of one side. They should have a non-slip surface.

Other Design Aspects. No sudden changes of slope to the bottoms of pools should be made where the depth of water is less than 6 ft. Fig. 69

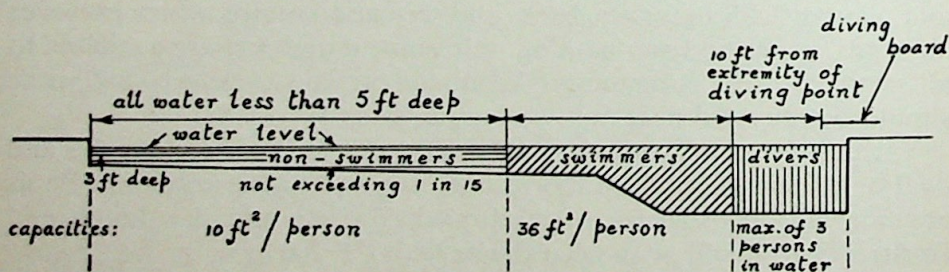


FIG. 69 Section through swimming pool.

shows a section through a typical pool and the varying capacities for different depths and conditions. A 110 ft $\times$ 42 ft pool has a capacity of 300 to 400 persons.

Depths of water are usually indicated at 1-ft intervals, together with the full depth at each end. Lane markings, above which the competitors swim, are generally 3 in. wide. Ladders and steps into the pool are best recessed and handrails are normally $1\frac{1}{2}$ in. diameter of stainless steel. Diving boards may be of timber, aluminium or fibre glass on a tubular steel or reinforced concrete frame. Underwater viewing windows are useful for diving and swimming instruction.

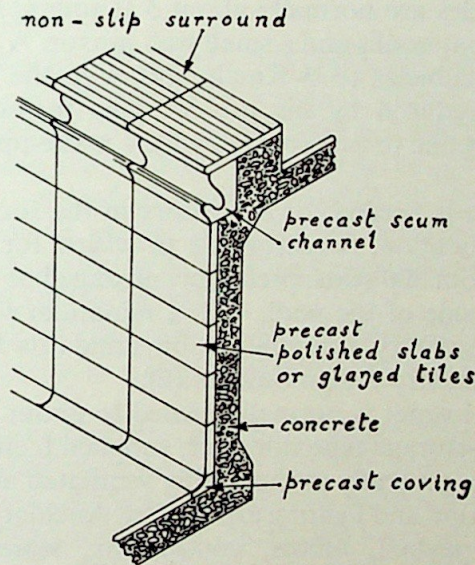


FIG. 70. Swimming pool detail.

In outdoor pools a raised edge helps to prevent dirt and leaves blowing into the pool, and it should be not less than 12 in. wide and 6 in. deep. The edge is normally formed in non-slip tiles and the pool lined with glazed or polished tiles, with junctions rounded to assist cleaning, as illustrated in Fig. 70.

Side-walks surrounding the pool should be at least 6 ft wide at the sides, 10 ft wide at the shallow end and 11 ft wide at the deep end. They should fall away from the pool to surface water outlets and be of impervious, durable, easily cleansed and non-slip material.

A scum trough, as shown in Fig. 70 should be provided on all sides of the pool, so that any floating impurities can be removed. The edges of the trough also provide a hand-grip for swimmers.

Swimming pools should be accessible only through a changing room past lavatories and through a pre-cleansing area. Pre-cleansing equipment

consists of shower-baths and foot-baths, preferably supplied with hot and cold water, adjustable mixing apparatus and soap. Sanitary accommodation should consist of a minimum of 1 W.C. for each 40 women and 1 W.C. and 1 urinal stall for each 60 men.

Swimmers' clothes may be stored in lockers, on hangers, in baskets or changing cubicles. The hanger system is very popular with women but men often favour baskets. In both cases central racks are required, which are operated by an attendant.

Changing cubicles are normally about 3 ft square and are provided with a seat, two coat hooks and a small wall mirror. A normal provision is about 5 male cubicles to 3 female, although the number of male cubicles can be reduced by the use of some mass-changing rooms. Women swimmers like to be provided with a make-up room fitted with hairdriers.

Some provision is needed for spectators in the form of seating and sanitary accommodation. A reasonable provision for a 110 ft $\times$ 42 ft pool would be about 300 seats, preferably arranged on the amphitheatre principle on one side of the pool, with a minimum width of 20 in. per person. Suitable sanitary accommodation standards for spectators are detailed in the Ministry design bulletin (6).

Swimming pool water is normally heated to about 72 to 76°F (22 to 24°C) with a non-storage type calorifier, supplied from the main boiler. Covered pools are generally mechanically ventilated and high standards of thermal insulation and lighting are needed. Ancillary accommodation may include a paybox, offices, control-box, stores, bath laundry, refreshments and café, instructor's room, first-aid room, plant room, etc.

Purification of Pool Water

It is essential that a high standard of purification of pool water is maintained, to prevent any possibility of outbreaks of disease amongst swimmers. Baths generally operate on the continuous filtration system, whereby the water in a pool is circulated continuously through a filter while the bath is in use. The normal 'turnover period' for indoor pools is 4 hours, although this may be possibly be increased to 6 hours for outdoor baths with normal loads. The clarity of the water can be measured with the aid of a target and viewing tube, described in the Ministry publication (7).

Aeration of the water after filtration is useful in maintaining bacterial purity. Sterilisation, usually with chlorine gas, is essential, to maintain a concentration of not less than 0.2 or more than 0.5 parts of chlorine per

million of water. Breakpoint chlorination is widely practised with good results and tests for residual chlorine in the filter effluent and pool water should be carried out using the orthotolidine test.

The purified and re-aerated water normally re-enters the pool at the shallow end, through several submerged inlets, although some pools have side inlets in addition. Provision should be made for both surface and bottom draw-off.

Swimming Bath Costs

The Ministry design bulletin No. 9 (8) provides useful information on recent swimming bath costs. For instance, taking prices adjusted to 31st December 1963, 110 ft × 42 ft single covered pools with 1 and 3 metre diving boards, café and sun-bathing terrace, and provision for 130 to 200 spectators, ranged between £140,000 and £180,000. Those with 5 metre diving boards, greater provision for spectators and more ancillary features, such as slipper baths, club rooms and bath manager's flat, ranged from £340,000 to £400,000.

At the other end of the scale, covered baths with 3 pools and games facilities at Coventry and Hampstead each cost over £1 million (December 1963 prices).

The bulletin shows that site conditions, water table and ground levels have an appreciable effect on cost. Other features with a considerable influence on costs include type of diving facilities, standard of finish (which must be high), amount of circulation space and extent of spectators' accommodation. The bulletin points out that teaching pools receive constant use from school classes, children on holiday and many other users, and the water needs treating at least once every 1½ hours. They also need separate changing rooms, each capable of taking at least 30 children.

It was considered that open truss roofs are the most suitable, giving ready access to engineering services, and that many pool halls were over-glazed, causing condensation, heat loss, glare and reflection problems. Double glazing of pool halls is considered essential if condensation and heat loss are to be minimised.

Completed Schemes

Some of the more outstanding features of completed schemes may be of interest to readers. The Hampstead swimming bath has a most impressive elevational treatment of stone facing, horizontal precast concrete louvres and black exposed aggregate slabs. It contains a major pool, minor pool, teaching pool and gymnasium. The two main pool halls are

separated by a block of tiered seating in the form of an inverted 'V', which can accommodate a total of over 1,400 spectators. This seating encloses administrative offices at the top, warm baths and showers at the intermediate entrance level, and the principal changing rooms at the lowest level adjacent to the pool surrounds. During the winter months the minor pool is covered over with a timber floor for use as badminton courts or as a secondary gymnasium. The cafeteria forms a bridge between the minor pool and the gymnasium, with views over both through glazed screens. The basement contains the boiler, filtration and ventilation plants, laundry, workshop and stores.

The swimming baths building is constructed of 230 ft long prestressed concrete beams over the main pool halls, supported by slender reinforced concrete columns with a boardmarked finish, which can be seen in Plate XV. The roofs are of lightweight concrete slabs. The horizontal louvres of reconstructed Portland stone, are bracketed to the columns at an angle to admit maximum light, yet excluding the direct rays from the sun and restricting glare and solar heat gain. The pool halls and changing rooms are finished with white mosaics on walls and floor and the pools are finished with blue tiles (9).

At Thurrock swimming bath a walking subway extends around three sides of the pool for easy maintenance of services, and on the fourth side the subway opens out to form the plant room. The pool hall has a structural steel frame supporting latic girder roof trusses.

At Aberavon swimming bath, seating in tiers to accommodate 1,000 spectators is provided on one side of the pool, while the other side, overlooking the promenade, is fully glazed with access for swimmers onto a sun bathing terrace. The pool slab and wall thicknesses vary from 9 to 18 in., and there are no expansion joints within the pool itself. P.V.C. water bars were provided at all construction joints. The framework consists of post-tensioned *in situ* concrete three-pinned portal frames at 20-ft centres and the roof cladding consists of asbestos cavity decking, weatherproofed with 3 layers of felt and sprayed with limpet asbestos on the underside.

The pool surround and tank are finished with $\frac{1}{2}$ in. thick ceramic tiling, wall surfaces to dado height are of cement glaze and other wall and ceiling surfaces are asbestos sprayed. The spectators' terrace is covered with vinyl tiles and nosings. Heating is by gas-fired boilers and two calorifiers. The pool is illuminated by 24 underwater flood-lighting units, mounted in gunmetal housings cast into the reinforced concrete walls behind a panel of toughened glass, set in a neoprene gasket and accessible from behind the structural walls (10).

The swimming bath at Cambridge has a convenient and economical

layout. Essentially the building consists of a pool hall with a main pool and learners' pool, with a basement containing the plant room below the side gallery for spectators, an entrance hall at one end, with male and female changing accommodation opening off it on either side at ground floor level, and a café above the entrance hall overlooking the length of the pools. Circulation space is kept to an absolute minimum (11).

A lido at Kingston upon Hull used off-peak electricity to heat the water in the pool by a three-phase electrode boiler and a thermostatically controlled water-to-water calorifier. About 5,000 yd² of lawn are provided around the pool with sun-bathing slopes, protected from cold winds on the northern and eastern sides by close-boarded fencing.

Maintenance of Swimming Baths

Pools are normally periodically cleansed by scouring the sides with a brush and any visible scum is removed with a long skimming pole. It is desirable that the bath manager or superintendent should keep records of the number of bathers and a daily log of the performance of the filtration plant, etc., recording such particulars as:

- (1) Hours worked by plant.
- (2) Washing of filter units and time taken.
- (3) Power consumed by filters.
- (4) Weight of chemical used, including liquid chlorine gas.
- (5) Amount of make-up water taken from mains.
- (6) Notes on alkalinity, clarity and chlorine content of pool water.
- (7) Remarks on any unusual characteristics of the pool water or difficulties arising with plant (7).

PUBLIC CONVENIENCES

Public conveniences are needed in villages as well as towns and their siting, construction and maintenance are matters which are of direct concern to the municipal engineer. Public conveniences are required in the centres of towns and larger villages, at neighbourhood centres, on seaside promenades and in public open spaces of various kinds. In many towns they are far too widely spaced, and a suitable provision would probably be at about $\frac{1}{4}$ mile intervals in heavily frequented areas, so that no person has to walk more than 200 to 300 yd to reach one. Adequate but discreet signposting is necessary to indicate their whereabouts.

Construction

In years gone by most public conveniences were constructed below ground, but today few are so sited apart from those with access from subways at major road intersections. Public conveniences in attractive facing bricks, with flat roofs and deep white fascias, can be quite pleasing in appearance. Plenty of obscured glazing is needed to give ample natural light inside them.

Dividing partitions between W.C. cubicles can be constructed in a wide variety of different methods. From rendered concrete block and half-brick walls to many forms of thinner partition, such as zinc coated steel sheets with a timber, fibreboard or bitumen bonded glass core; insulation board faced both sides with painted hardboard, with hardwood or aluminium plinth and capping; synthetic resin laminated sheets; hardboard faces with a core of resin bonded cork granules, finished with plastic; a latticed or expanded polystyrene core faced with plywood, plastic sheet, veneered board, asbestos board, etc.; or precast terrazzo slab partitions. Dividing partitions are often about 5 ft to 6 ft high with a 6 in. to 12 in. gap below the partition to facilitate cleaning, and with the fronts to the cubicles about 6 ft 6 in. in height.

Common sizes for W.C. cubicles are 5 ft 6 in. long by 2 ft 6 in. or 2 ft 9 in. wide, with 2 ft or 2 ft 3 in. door openings. Floor finishes need to be impervious and durable, and the selection is often determined by the funds available—granolithic, floor quarries, ceramic tiles, composition flooring and terrazzo are all used extensively. Wall finishes can also take a variety of forms from glazed wall tiling in high class work, to the many colours and patterns available in sprayed cement glaze, or the rough Tyrolean finish, to minimise the nuisance from writing on walls.

Sanitary Appliances

The usual form of W.C. is the white glazed ceramic pedestal wash-down closet with a combined pan and trap, with a black plastic seat and low-level flushing cistern of porcelain, enamelled or galvanised cast iron or pressed steel, plastic or ceramic ware, generally of 2 gal capacity. Flush pipes can be of steel tube, copper with natural or chromium plated finish or polythene.

The most common form of urinal is the stall type, with stalls 2 ft wide and back and channel in one piece. A few authorities use the bowl or slab types. Ranges of urinals are flushed from an automatic flushing cistern with discharges at least once in 25 minutes. Flush pipes are usually of copper or galvanised steel tube, terminating with spreaders in each stall.

Local authorities are now required to provide hand washing facilities in public conveniences, with a constant supply of water, preferably hot, soap and hand-drying equipment. The hand-drying equipment may consist of roller linen towels, paper towels or hot-air driers, usually foot-operated. Lavatory basins are usually ceramic and 22 in. $\times$ 16 in. in size, with copper wastes.

Maintenance of Conveniences

Most local authorities are faced with continual damage to and mis-use of public conveniences, and wherever possible it is desirable to have a full-time attendant to restrict the amount of damage and keep the conveniences in first-class condition. With small conveniences, it is sometimes practicable to combine the post of public conveniences attendant with that of car park attendant, where the two facilities adjoin one another. A survey carried out by a lady architect, Mrs K. McBretney, in Bedford in 1963, revealed that over 90 per cent of the women covered by the survey tried to avoid using public conveniences and over 95 per cent of the women did not use the W.C. seats, largely because they were often contaminated. Obviously, a much higher standard of cleanliness in public conveniences is generally needed and there is a strong case for employing women attendants in ladies conveniences. The provision of urinettes for women deserves careful consideration.

There is much to be said for eliminating all charges for the use of W.C.s, even if only to prevent the continual and costly damage to coin locks.

PUBLIC SHELTERS AND CAFÉS

Municipal engineers are frequently required to provide public shelters either on their own or in conjunction with other features such as cafés. Various forms of construction are employed, from precast concrete panels to timber framing clad with horizontal ship-lay or waney edged boarding, and brick or concrete block walls, often roughcast and painted. All these incorporate glazing, often using standard metal casements in the simpler structures. Roofs range from flat concrete slabs and built-up felt or copper covered flat roofs to pitched roofs covered with tiles, wood shingles or even thatch. 'Armorplate' is often used for glazing and slatted teak seats are quite popular. The modern tendency is often to provide shelters with a light metal frame and plenty of glazing.

The Wish Tower sun lounge and café at Eastbourne show how attractive this type of development can be. The building stands on the mound

of one of the old Martello towers overlooking the sea. This development is illustrated in Plate XVI and consists of a café to seat 250 persons, a sun lounge, kitchen and lavatories. There is a terraced tea lawn at the rear of the building and the Wish Tower has been restored and its moat converted into a quiet garden. Balconies are cantilevered from the café and sun lounge over the lower parade and overlook the sea.

The structural framework is of timber columns supporting ply-box primary and secondary beams. The columns are enclosed within an anodised aluminium cladding, which forms part of the structural frames for the large windows, which can be seen in Plate XVI. The roof is covered with a plastic laminate and the ceiling consists of light diffusing sheets.

AIRPORTS

With large authorities, there is the possibility that the engineer may be concerned with the construction and maintenance of an airport. Great care is needed in the siting of airports, to secure sites which are free from obstruction or nuisance, readily accessible and with space for expansion. Both Birmingham and Liverpool municipal airports have received substantial extensions in recent years to accommodate an increasing volume of air traffic and larger aircraft (12).

In July 1965, the first completely new civil airport in this country was officially opened at Castle Donington to serve the East Midlands. It was constructed on the site of an old R.A.F. station. on behalf of a joint committee representing five authorities: Derby C.B., Derbyshire C.C., Leicestershire C.C., Nottingham C.B. and Nottinghamshire C.C., with one officer from each authority filling a key position.

The whole of the airport constructional work, to Viscount standard, was completed in 12 months. Close collaboration was maintained with the divisional controller of the Ministry of Aviation, to ensure that the initial planned development would meet present requirements and be capable of incorporation in extension schemes. The layout of the airport is shown in Fig. 71.

The paved runway is 5,850 ft long by 150 ft wide and there are 60 ft wide taxiways and a terminal apron, 722 ft $\times$ 368 ft in size. These have a constructional depth of 21 in., consisting of 6 in. consolidated granular sub-base, using the crushed concrete from the old runways, overlaid with a 4 in. thickness of weak concrete, fabric reinforcement (8.6 lb per yd^2) and an 11 in. fully dowelled concrete pavement, laid by machine in bays 60 ft long by 26 ft wide on the continuous system. The taxi-track to

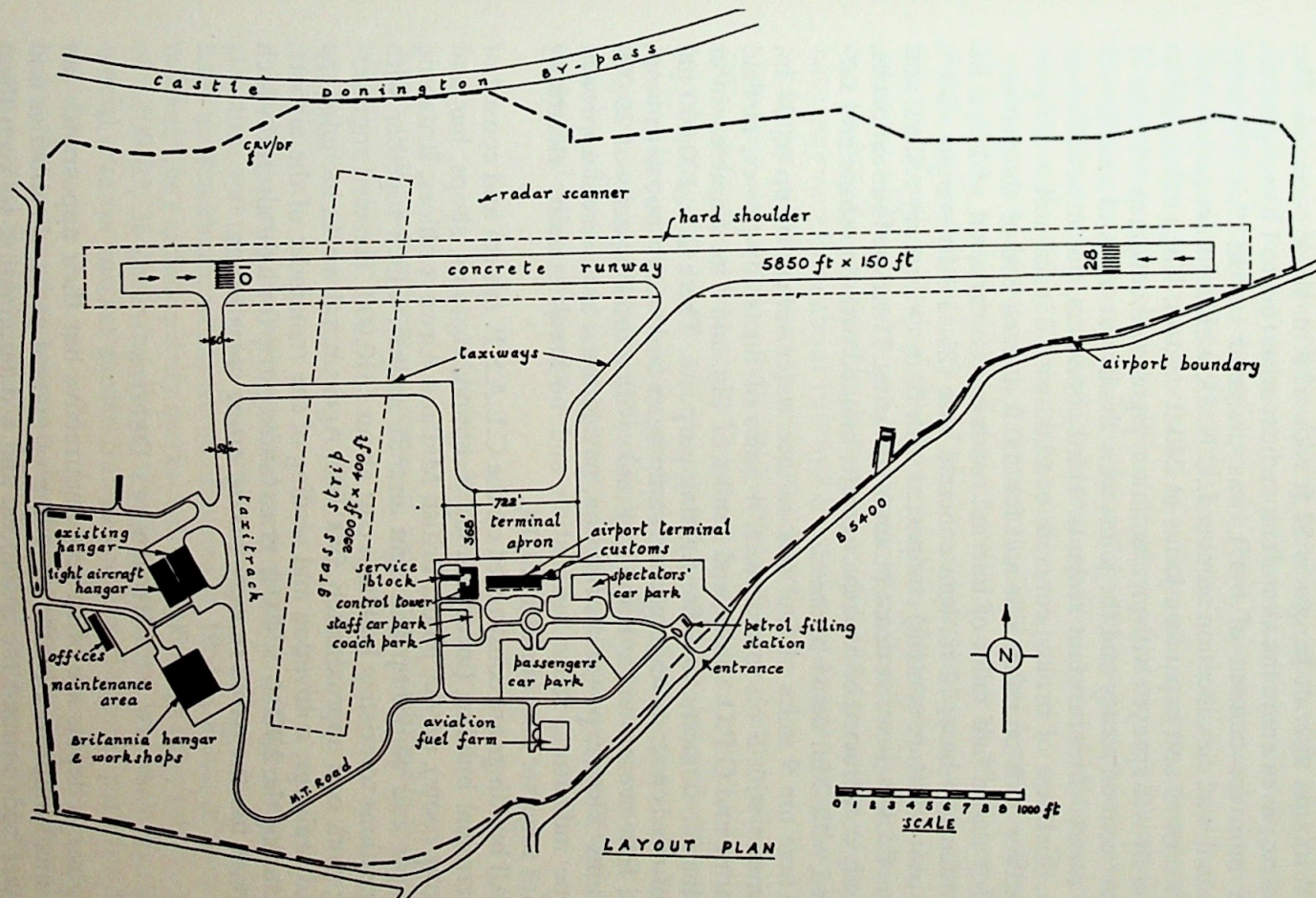


FIG. 71. East Midlands airport, Castle Donington.

the Britannia aircraft hangar is 52 ft wide of 9 in. thick concrete. The concrete pavement in the aircraft movement areas (6.3 to 1 by weight mix with moisture content of 0.45), was designed to the Air Ministry nominal load classification number L.C.N. 55, with contraction joints at 60-ft centres and expansion joints at 240-ft centres. The surface of the concrete was sprayed with an aluminium pigmented curing membrane of 90 per cent efficiency and the joints were finally cut out and sealed with hot poured fuel resistant sealants. Hard shoulders, constructed of an 8 in. thickness of broken concrete overlaid with 6 in. of soil, were provided for 75 ft on either side and for 200 ft at each end of the runway.

One and a half miles of internal roads are constructed with a 3 in. granular sub-base, 12 in. lean concrete base (21 to 1 by weight with 5 per cent moisture content) compacted with 10 cwt vibratory rollers, and 4½ in. thick two-course dense bitumen surfacing. There are four car parks, mainly constructed of broken concrete, blinded with limestone and surfaced with 2 in. dense bitumen.

There are 9 miles of foul and surface water sewers of up to 24 in. diameter with 5 oil interceptors, 4 miles of ducts for power, airfield lighting and G.P.O. cables, and 2 miles of 4 in. and 6 in. diameter water mains for domestic and fire fighting purposes. There is a 100,000 gal reinforced concrete underground static water tank with a booster pump, and four overground aviation fuel tanks with a total capacity of 39,000 gallons. Electric power distribution, navigational aids, visual approach slope indicators, radar installation and no-break standby electricity plant together cost about £120,000.

All buildings are constructed on the C.L.A.S.P. system and consist of a terminal building (incorporating reception, customs, shops, bar and dining room), service block, British Midland Airways offices, Britannia hangar and workshop and light aircraft hangar, which together with alterations to existing buildings cost about £310,000. The civil engineering work cost approximately £900,000. Agricultural works included the land drainage, cultivation and seeding of the remainder of the airport, including the 2,900 ft × 400 ft grass landing strip for light aircraft which cannot use the paved runway during strong cross winds.

HIGHWAYS DEPOTS

Highways depots are often very unattractive but their appearance can be much improved by the provision of grassed areas, shrubberies and flower beds around the entrances, and a determination to keep them tidy. Two separate gateways are usually provided—one for incoming

vehicles and the other for outgoing vehicles—often with weighbridges. Access by rail and/or water can be useful on occasions. The depot needs siting away from the central area of a town, but reasonably convenient for serving all municipal work in the town.

The buildings generally consist of offices, mess rooms, stores, workshops and garages, and possibly a depot superintendent's house. Mess rooms require adequate facilities for eating meals with adjacent lavatory and clothes storage and drying accommodation. A suitable construction is brick walls with a flat concrete roof.

Garages can conveniently be constructed of 9 in. brick walls, with piers as required, and steel stanchions and sliding doors on the front face. Roofs can consist of steel roof trusses and purlins supporting asbestos cement sheeting, and probably a number of perspex sheets to give additional light. One or two inspection pits covered with loose boards can usefully be provided in the larger garages. The dimensions of garage bays may vary from about 19 ft by 8 ft for vans and trucks to 25 ft by 10 ft for larger vehicles, such as refuse collectors.

Storage areas need subdividing with brick or concrete walls to take different highway materials. These are best sited at a higher level for easy loading into lorries at a lower level. With some materials the use of loading hoppers can make for greater efficiency. The provision of a large concrete mixer at the depot, for the supply of ready-mixed concrete to a number of smaller jobs, can be very useful. Ancillary equipment includes petrol and diesel oil pumps.

OTHER BUILDINGS

Some of the other principal types of municipal building are now described.

Markets

Municipal engineers are sometimes responsible for the design, construction and maintenance of markets. A typical example is the market halls at Blackburn, which were completed in 1964 at a cost of over £1 million. They include a daily market hall of 26,000 ft², a daily fish market of 4,500 ft², 36 perimeter shops, a large restaurant, wholesale market, special area for market garden traders and a roof-top car park for 330 vehicles.

Another outstanding scheme is the Pannier market at Plymouth, where accommodation is available for 150 permanent stalls and 30 to 40 daily stalls. The main hall is 220 ft by 150 ft and on three sides it is enclosed by

43 shops, the majority of which have shopfronts facing into the main hall, in addition to fronting onto surrounding streets. A gallery over some of the ground floor shops takes refreshment stalls.

The building has a reinforced concrete frame, with a shell roof carried on portal frames at 32-ft centres, to provide a light and airy unrestricted floor area. Concrete infilling walls are faced externally with precast concrete slabs, using local stone aggregate, and windows are of aluminium. Permanent stalls are of precast concrete units, erected on a raised concrete base with light tubular columns to carry the fascia.

In the Brighton open market, the stalls are of two sizes: 17 ft $\times$ 17 ft and 12 ft $\times$ 12 ft. Waterproof canvas blinds are provided for night protection and stalls also have gaily-coloured sun blinds. All stalls have lavatory basins and electric light. The fishmongers' and butchers' stalls have tiled dados and tiled fish or meat slabs and a sink, while water points in the fish slabs enable a spray to be used in hot weather.

Mortuaries

The normal provision in mortuaries is a screened entrance, post-mortem room, refrigeration room with a number of compartments, viewing chapel and possibly a separate viewing chamber, morticians' office, doctor's room with separate entrance, waiting room and lavatories. It is usual for the whole of the accommodation to be provided at one level.

Bus and Coach Stations

The following very sound principles were adopted in the design of a coach station at Torquay:

- (a) All coaches move from the entrance to a separate exit, thus eliminating waste of space by manoeuvring vehicles.
- (b) Segregation of loading and unloading coaches.
- (c) Provision of a free running lane clear of all waiting vehicles, to permit any one vehicle in the park to readily move out.
- (d) Lettering and numbering of loading bays to help passengers to identify coaches.

At this coach park the terminal building contains a café, left luggage facilities, waiting room and toilets including showers.

Concert Halls and Theatres

Municipal engineers at holiday resorts and large towns may be called upon to provide concert halls and theatres. A typical example is the concert hall constructed at Torquay in 1960, at a cost of about £100,000.

It contains a concert hall, sun lounge, shop, booking hall for boats, bar and underground lavatories. The concert hall seats about 1,100 people and has a stage 60 ft $\times$ 26 ft, with dressing rooms on both sides and a store room below. The building has a steel frame and the external cladding is of local limestone and white rendered brickwork to give a light coloured finish. The concert hall walls are panelled internally with veneered plywood. The building is heated with an oil-fired central heating system and it is mechanically ventilated.

Municipal Offices

Municipal engineers are sometimes concerned with the construction of new municipal offices, or extensions thereto, particularly when the engineer's department has its own architectural and structural engineering sections. One such scheme is the attractive new municipal offices constructed at Bedford in 1963, at a cost of about £330,000 (including £27,000 for furniture and equipment) and with accommodation for 240 staff. It is 6 storeys in height, including a penthouse, has a total floor area of 45,284² ft and contains two lifts.

The building was designed on a longitudinal module of 4 ft 6 in. with a normal depth of office of 18 ft, to take advantage of natural lighting. A clear passage space of 6 ft down the centre of the building provides for general circulation and the normal ceiling height is 9 ft 2 in. There is a link with the existing town hall which contains the civic suite and some offices.

The steel-framed building is clad with 3 in. Darley Dale stone, which gives dignity to the structure and harmonises with surrounding buildings. Other facing materials used are Roman travertine for infill between windows and Lido marble for pilasters. Large areas of glass on the east and west façades give abundant natural lighting.

Most of the partitioning is demountable and the fluorescent lighting installed at ceiling level, is also designed for simple alteration. The building is heated by an oil-fired central heating plant with low pressure hot water circulated to convectors below window sills, running continuously on both sides of the building. Toilet facilities are provided on each floor.

Community Centres

It is generally agreed that community centres should be provided on the basis of neighbourhood units, i.e. serving 5,000 to 10,000 population. The Ministry of Education suggested standards of accommodation and prepared typical plans (14).

The suggested accommodation is a large hall, about 70 ft $\times$ 45 ft, with gallery, stages, dressing rooms, cloakrooms and lavatories; gymnasium, 70 ft $\times$ 40 ft, with changing rooms and showers; small purpose hall; large common room; kitchen; games room; three general purpose rooms library and reading room; accommodation for a warden; entrance hall; and separate cloakrooms and lavatories for both sexes. Where suitable school premises are available for evening use the facilities can be much reduced.

WARTIME FUNCTIONS

In time of war the municipal engineer undertakes a number of different functions. These include the provision of air raid shelters and static water tanks, the construction and adaptation of buildings for wartime uses, organisation of bomb damage repairs and various civil defence duties. The majority of new schemes of municipal engineering work are suspended for the period of the emergency, but maintenance work and operation of essential services have to continue with a much depleted labour force.

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CHAPTER THIRTEEN

Contract Organisation

THE municipal engineer has to be able to advise on the best type of contract to adopt for a particular job, or whether it is desirable to carry out the work by direct labour. He needs to have a thorough knowledge of the relevant conditions of contract and to be well versed in the preparation of drawings, specifications and often bills of quantities and estimates for municipal engineering work, as well as being able to direct work on site.

TYPES OF CONTRACT

There are basically eight types of contract which can be used for municipal engineering work, and each of these will now be described and their uses detailed.

(1) Bill of Quantities Contract

This is generally the soundest form of contract and incorporates a bill of quantities, in which all the component items of work are priced by the contractor to give the tender sum. The bill of quantities helps the contractor in pricing the job, and in the absence of this document he might have to prepare his own approximate bill in the limited time allowed for tendering.

Furthermore, the priced bill of quantities provides a basis for the valuation of variations, in addition to ensuring a common basis for tendering. It is good policy to use this form of contract on all but the smallest building and civil engineering contracts.

(2) Lump Sum Contract

In a lump sum contract the contractor undertakes to carry out the contract works for a fixed sum of money. The details of the project are

normally shown on drawings and described in a specification, but no bill of quantities is supplied. This form of contract is often used where the job is reasonably certain in character and small in extent, such as site-clearance work and small building projects, like pumping stations and public shelters.

(3) Schedule Contract

This may take one of two forms:

- (a) The local authority supplies a schedule of unit rates covering each item of work likely to be encountered, and contractors are required to state a percentage (up or down) for which they are prepared to undertake the work.
- (b) The more usual method is to require contractors to insert a rate against each item of work in the schedule. It is good practice to include approximate quantities to assist contractors in pricing the schedule and for the subsequent comparison of tenders.

This type of contract is mainly used for maintenance work, but occasionally schedules of rates are used as a basis for negotiated contracts.

(4) Cost plus Percentage Contract

In a cost plus percentage contract, the contractor is paid the actual cost of the work, plus an agreed percentage of the actual or allowable cost to cover overheads, profit, etc. It is useful in an emergency, when there is insufficient time to prepare a detailed scheme before work is commenced, but it will be apparent that an unscrupulous contractor could increase his profit by delaying the completion of the works. No incentive exists for the contractor to complete the works as quickly as possible or to try to reduce costs.

(5) Cost plus Fixed Fee Contract

In this form of contract, the contractor is paid the actual cost of the work plus a fixed lump sum, which has been previously agreed upon and which does not fluctuate with the cost of the job. It is not a particularly good form of contract, although it is superior to the cost plus percentage type contract, as there is some incentive to the contractor to complete the job as speedily as possible and so release his resources for other work.

(6) Cost plus Fluctuating Fee Contract

In this type of contract, the contractor is paid the actual cost of the work plus a fee, the amount of the fee being determined by the application of some form of sliding scale to the allowable cost of the work. Thus the lower the actual cost of the works, the greater will be the fee that the contractor receives. An incentive thus exists for the contractor to carry out the work as quickly and cheaply as possible, and it constitutes the best of the 'cost plus' or 'cost reimbursement' type of contract, from the employer's point of view.

(7) Target Contract

In a target contract, a basic fee is quoted as a percentage of an agreed target estimate obtained from a priced bill of quantities. The target estimate may be adjusted for variations in quantity and design and fluctuations in labour and materials costs, etc. The actual fee paid to the contractor is obtained by increasing or reducing the basic fee by an agreed percentage of the saving or excess between the actual cost and the adjusted target estimate. Thus there is a definite incentive to the contractor to complete the work as speedily and economically as possible, but it involves a considerable amount of contract document preparation, including a bill of quantities.

(8) All-in Contract

With this type of contract, the employer gives his requirements in broad outline to the contractor, who submits full details of design, construction and cost for the project. It is suitable in a few special cases, such as gas and chemical works, oil-refineries and nuclear power stations, but is unlikely to be suitable for the majority of municipal engineering works (see reference 1 at the end of this chapter).

PARTIES TO A CONTRACT

The principal parties to a contract for municipal engineering work are the employer (local authority) and the contractor. The contract is for a definite job of work, as detailed in the contract documents, to be done by the contractor in return for payment from the employer.

The engineer, as representative of the employer, is mentioned in the contract because he is responsible for preparing the scheme and supervising the constructional work. He also has powers to fix rates for varied

work and to settle disputes, and he may appoint a resident engineer to represent him on the site. The engineer for the contract may be the local authority's own engineer or an outside consulting engineer, engaged for the particular contract.

Readers requiring information on the law relating to building and civil engineering contracts, which is a complex subject, are referred to the books listed at the end of the chapter (2).

CONTRACT DOCUMENTS

A full set of contract documents will be needed for the majority of municipal engineering jobs which are carried out by contractors. The number and form of the contract documents will vary according to whether the job is mainly building or civil engineering in character, as the contractual procedures vary in each case. The Banwell report urged the adoption of a common form of contract for both building and civil engineering work, but practical difficulties arise due to differences in the method of pricing, supervision and execution of the two types of work (3).

In the majority of cases, the work will be of a civil engineering nature and the contract documents will consist of:

- (1) Form of Contract.
- (2) General Conditions of Contract.
- (3) Contract Drawings.
- (4) Specification.
- (5) Bill of Quantities.
- (6) Form of Tender.

In the case of a building contract, the specification will not usually constitute a contract document where a bill of quantities has been prepared.

The Form of Contract is a formal agreement between the local authority (the employer) and the contractor for the execution of the work in accordance with the other contract documents. This is generally covered by the Form of Agreement contained in the Civil Engineering Conditions of Contract (4).

The Form of Tender constitutes a formal offer by the contractor to execute the contract works in accordance with the contract documents for the tender sum. It also generally states the contract period, within which the contractor is to complete the works.

The form of tender mainly used in municipal engineering work is the

form contained in the General Conditions of Contract for use in connection with Works of Civil Engineering Construction (4). This form of tender provides for a bond amounting to 10 per cent of the tender sum, whereby the contractor provides two sureties (or a bank or insurance company) who are prepared to pay up to 10 per cent of the tender sum if the contract is not carried out satisfactorily. An appendix covers such matters as time for completion, amount of liquidated damages, maintenance period and minimum amount of interim certificates.

GENERAL CONDITIONS OF CONTRACT

Conditions of Contract Generally

The General Conditions of Contract lay down the terms under which the work is to be undertaken, the relationship between the local authority (the promoter or employer), the engineer and the contractor, the powers of the engineer and the terms of payment to the contractor. In most municipal engineering contracts it is customary to use the General Conditions of Contract for use in connection with Works of Civil Engineering Construction, often referred to as the 'I.C.E. Conditions' (4).

With building jobs, it is better to use the standard conditions issued under the sanction of the Royal Institute of British Architects and various other bodies, and generally described as the 'R.I.B.A. Conditions' (5). There are four alternative forms for use where quantities do or do not form part of the contract and for use on local authority contracts and for private work respectively.

When the limited size of the job does not justify the use of the full set of standard conditions of contract, an abbreviated set of conditions, often worked up from the appropriate set of standard conditions, is frequently employed. For certain specialised classes of civil engineering work the responsible authorities have introduced further clauses, which modify or supplement the standard clauses of the I.C.E. Conditions. A typical example is the clauses introduced by the Ministry of Transport in connection with contracts for roads and bridges. The Institution of Structural Engineers has issued a set of standard conditions for use on structural engineering contracts (6).

Civil Engineering Conditions of Contract

A summary of the main provisions of the I.C.E. Conditions follows:

Clause 2 details the duties and powers of the engineer under the contract, and these are particularly important.

The Contractor is entitled to two sets of drawings (clause 7) and is required to examine the site before submitting his tender (clause 11).

Clause 14 requires the contractor to submit a detailed programme showing the order and method of carrying out the work.

Under clause 16, the engineer may require the contractor to remove from the works any person who misconducts himself or who is incompetent or negligent.

The contractor is responsible for the true and proper setting out of the works and for the provision of all necessary instruments and labour (clause 17).

The contractor is also responsible for the care of all permanent and temporary works (clause 20), insurance of the works (clause 21), damage to persons and property (clause 22), and giving of notices and payment of fees (clause 26).

It will be noted from clause 30 that the passage of traffic to the site is to be organised, as far as possible, so as to reduce all claims for extraordinary traffic to a minimum.

Clause 34 provides for the payment of wages and observance of hours and conditions of labour not less favourable than those established for the trade or industry in the district where the work is carried out.

The requirements with regard to costs of samples and tests (clause 36) and the inspection and removal of improper work and materials (clauses 38 and 39) are very important.

Clause 40 gives the engineer the right to suspend the progress of the works but, in the majority of cases, any extra costs incurred by the contractor as a result of the suspension will have to be borne by the local authority (the employer).

The contractor is required to commence the works within 14 days after receipt of the engineer's written order to proceed. Clauses 43, 44, 47 and 48 relating to time for completion, liquidated damages for delay and certificate of completion, all have far-reaching effects.

The contractor is required to make good any defects, arising from the use of materials or workmanship not in accordance with the contract, appearing during the maintenance period (clause 49).

The engineer may alter the extent or character of the works, by orders in writing, without invalidating the contract and the additional or amended works shall be valued at billed rates, as far as practicable (clause 51). The engineer is given the power to fix rates for varied work, and provision is also made for carrying out certain work on a daywork basis (clause 52). 'Daywork' is the method of valuing work on the basis of the time spent by the workmen, the materials used and the plant employed. This method is used when it is impracticable to value work at the billed

rates, and the only satisfactory method of evaluation of the work is on a daywork basis. The *Standard Method of Measurement of Civil Engineering Quantities* details three ways of valuing work on this basis (10).

Clause 53 vests the ownership of all constructional plant, temporary works and materials on the site in the local authority (the employer), and these cannot be removed by the contractor without the written consent of the engineer.

The quantities are to be measured in accordance with the *Standard Method of Measurement of Civil Engineering Quantities*, and the work as executed is to be measured on completion (clauses 56 and 57).

Under clause 58, both selected suppliers of goods and selected sub-contractors are referred to as 'nominated sub-contractors' on a civil engineering contract. No cash discounts are legally payable to the contractor, unless he pays the sub-contractor on the direction of the engineer before he himself receives payment from the local authority (the employer), although this procedure is not always followed in practice due to practical difficulties in operation. *Note:* Nominated sub-contractors on civil engineering contracts are specialist tradesmen, merchants and others carrying out work or supplying goods for which provisional or prime cost sums are included in the bill of quantities. These sub-contractors are selected by the engineer, on behalf of the local authority, but they receive their instructions and payment from the main contractor. In building contracts the person nominated for the supply of goods is described as a 'nominated supplier'.

The contractor submits to the engineer a monthly statement of the estimated value of permanent work executed and, if it exceeds the minimum amount for interim certificates, the engineer issues a certificate authorising payment to the contractor, less retention money (clause 60).

The engineer is authorised to settle any dispute arising under the contract, but if the contractor is dissatisfied with his decision he can take the matter in dispute to arbitration (clause 66).

The Variation of Price (Labour and Materials) clause can be incorporated where it is not to be a 'fixed price' contract.

CONTRACT DRAWINGS

The contract drawings depict the nature and scope of the works to be carried out under the contract. They must be prepared to a suitable scale and be in sufficient detail to permit a contractor to satisfactorily price the bill of quantities and carry out the work. For instance, sewer plans are frequently drawn to a scale of 1/2500 or 1/500, with sections prepared to

an exaggerated scale, such as 1/2500 horizontal and 40 ft to 1 in. vertical. Road plans are sometimes drawn to 1/500 scale, but scales of 32 and 64 ft to 1 in. are now being used to an increasing extent (multiples of $\frac{1}{8}$ in. scale). Manhole and gulley details are usually drawn to a scale of $\frac{1}{2}$ in. to 1 ft.

All available information as to the topography of the site and the nature of the ground and water table level should be made accessible to contractors tendering for a job. Existing and proposed work must be clearly distinguished on the drawings. For instance, old and new sewers and other services can be depicted in different colours, whereas for alterations to buildings it is often desirable to prepare separate plans of existing and new work.

All drawings should contain an abundance of descriptive and explanatory notes, which should be clearly legible and free from abbreviations. Ample figured dimensions should be included on the drawings to ensure maximum accuracy in taking-off quantities and setting out the constructional work on the site.

Materials shown in section are best coloured or hatched for ease of identification, using the notation given in the relevant British Standard (7). Guidance is also given in the British Standard on the use of lines for various purposes; for instance, dimension lines are to be thin and continuous, with the dimension placed above the line and along it, and readable from the bottom or right-hand edge of the drawing.

This British Standard gives 13 recommended drawing sizes, ranging from 72 in. $\times$ 40 in. to 10 in. $\times$ 8 in. (sheet sizes as cut from roll). Where an engineer's department keeps a stock of ready printed negative sheets it will probably be decided to limit the number of sheet sizes to about 4 or 6. Recommendations are also included as to layout of drawing sheets and numbering of drawings. It is good practice to keep a card index of drawings and to enter on drawings the date and nature of any amendments.

One set of contract drawings will be used by the contractor on the site, and these will probably be supplemented by further detailed drawings during the course of the contract. Prints are obtainable on paper or linen, the latter being more suitable for rough usage on the site. Dyeline prints are not true to scale and can give rise to errors on scaling dimensions.

SPECIFICATION

The specification amplifies the information given in the contract drawings and bill of quantities. It describes in detail the work to be

carried out under the contract, including the nature and quality of the materials and workmanship. It includes details of any special responsibilities to be borne by the contractor, apart from those contained in the General Conditions of Contract. It may also contain clauses specifying the order in which various sections of the work are to be undertaken, methods of working to be adopted, and details of any special facilities that are to be afforded to other contractors.

Civil Engineering Procedure (1), recommends that the specification should also require tenderers to submit an outline programme and a description of proposed methods and temporary works with their tenders.

The specification will always be a contract document in civil engineering work, whereas with building contracts it is rarely a contract document if a bill of quantities has been prepared. There is a tendency on building projects to replace the specification with enlarged preamble clauses, at the head of each trade or works section in the bill of quantities.

A good arrangement for a specification covering civil engineering work is to commence with any special conditions and the extent of the contract. This can be followed with such items as list of contract drawings, programme, access to site, water and electricity supply, offices and welfare facilities, protection of existing services, trial borings, water level, etc. Then to follow with the main body of the specification, containing detailed clauses covering the various sections of work in the contract, commencing with materials in each case and then proceeding with workmanship and other clauses.

The Ministry of Transport specification for road and bridge works (8), adopts a rather different order: general clauses, workmanship, and materials and testing clauses. The workmanship clauses are subdivided into site clearance; new hedges, trees and shrubs; fencing; sewers, drains and manholes; earthworks; sub-bases, bases and hard shoulders; surfacings; and kerbs, channels, quadrants, edgings and paving flags. These are followed by workmanship clauses relating to structures, such as bridges, culverts and retaining walls, which are again subdivided into different classes of work such as piling; formwork; concrete; prestressing; brickwork; masonry; filling; riveted steelwork; welded steelwork; carpentry; joinery; and waterproofing. Readers may find the detailed clauses in this publication of considerable assistance as a guide in the drafting of specification classes.

Building specifications are usually subdivided into trades or works sections, similar to those adopted in the *Standard Method of Measurement of Building Works* (11). Readers requiring detailed information in

the drafting of building specification clauses are referred to the annual publication *Specification* (9).

The task of specification writing can be eased considerably by the extensive use of British Standards and Codes of Practice. The inclusion of British Standards ensures the use of good quality materials and components embodying the results of latest research, and assists in the standardisation of documents, with consequent benefit to contractors. Care must be taken to ensure that any references to British Standards include the appropriate class or type of material required when a number of classes or types are given in the British Standard.

The civil engineering practice is to give detailed descriptions of materials and workmanship in the specification clauses, but only very brief descriptions in the bill of quantities. Thus the civil engineering contractor will refer constantly to the specification when pricing the rates in the bill of quantities. Once the contract is under way the civil engineering method has much in its favour, with a good comprehensive specification as a separate and strictly enforceable document.

BILL OF QUANTITIES

Purpose and Contents of a Bill of Quantities

A bill of quantities consists of a schedule of the items of work to be carried out under a contract, with quantities entered against each item. The bulk of municipal engineering work will be measured in accordance with the *Standard Method of Measurement of Civil Engineering Quantities* (10), but building work is generally measured in accordance with the *Standard Method of Measurement of Building Works* (11). For road and bridge work the notes issued by the Ministry of Transport (12) may prove useful, although they conflict with some of the provisions of the *Standard Method of Measurement of Civil Engineering Quantities*.

One of the primary functions of a civil engineering bill of quantities is to provide a basis on which tenders can be obtained and, when the bills are priced, they afford a means of comparing the various tenders received. After the contract has been signed the rates in the priced bill of quantities can be used to assess the value of the work as executed.

The quantities should be as accurate as possible, although on civil engineering contracts the work is invariably remeasured on site, whereas in building schemes the remeasurement of work on site is mainly limited to substructural, drainage and similar work. Civil engineering billed descriptions are kept brief with frequent references to specification

clauses, whereas in building work detailed descriptions appear in the bill. In all cases, billed descriptions must indicate clearly the nature and scope of the work covered.

The unit rates entered by contractors against items in bills of quantities normally include allowances for overheads and profit, and in civil engineering bills they also have to include allowances for the majority of items of temporary work, such as trench timbering, keeping excavations free from water and levelling and ramming bottoms of excavations. Special items of temporary work, such as a cofferdam around a sewer outfall into a river, may call for special billed items in a civil engineering bill of quantities.

The actual arrangement of a civil engineering bill of quantities varies with the type of work being measured. For instance, a housing site preparation contract might conveniently be subdivided into the following sections:

- (1) Site preliminaries.
- (2) Site clearance and earthworks for roads.
- (3) Excavation for sewers, manholes, etc.
- (4) Sewer pipes and tubes.
- (5) Manholes.
- (6) Gullies.
- (7) Carriageway and kerbs.
- (8) Water mains.
- (9) Sundry and provisional items.

In the case of a sewage disposal works contract, the bill sections will probably relate to the component parts of the scheme, such as:

- (1) Outfall sewer.
- (2) Detritus chamber.
- (3) Pumping station.
- (4) Sedimentation tanks.
- (5) Storm-water tanks.
- (6) Percolating filters.
- (7) Sludge digestion tanks.
- (8) Humus tanks.
- (9) Sludge drying beds.
- (10) Effluent pipe.
- (11) Access road.
- (12) Ancillary works.

In each of these sections, the billed items will normally follow the

order of subsections contained in part IV of the Standard Method (10). In building work the bill is subdivided into trades or works sections.

Where the same constructional work is to be performed under different conditions, separate billed items should be given to enable the contractor to enter different prices against them. Typical examples are reinforced concrete in the base of a pump well below ground and the same material in the base of a water tower tank, 50 ft above ground level. Where the quantity of work is uncertain, such as making up soft spots in a road formation, then these items should be listed as provisional.

The Standard Method of Measurement of Civil Engineering Quantities permits the use of a system of comprehensive measurement for repetition work, mainly composite work of a uniform type of construction. A single billed item can be used although several classes of workmanship and materials are involved. Typical examples are retaining walls, tunnel work and pipe lines. In each case a subsidiary bill should be included in the description column, listing, in the recognised units of measurement, the quantities of the component materials and work required to provide a unit of length, e.g. one linear yard of tunnel lining.

Where the 'Variation of Price (Labour and Materials) Clause' operates the contractor is permitted to claim the increased costs, which occur after the date of tender, of labour, materials and consumable stores which are used on the contract. It is the usual practice to incorporate a schedule of basic rates at the end of the bill of quantities, in which the contractor can enter the basic prices of labour and materials on which his tender is based. In some cases the principal materials are entered in the schedule when the bill is being prepared, but the contractor can enter any other materials if he wishes to do so.

Units of Measurement

To secure uniformity of measurement, recognised units of measurement and general rules and principles are contained in the two measuring codes (10 and 11). The civil engineering units of measurement for the more common items of work are listed in Table 15. The application of the rules of measurement to specific examples of building and civil engineering work is illustrated in two books by the author (13 and 14).

TABLE 15. CIVIL ENGINEERING UNITS OF MEASUREMENT

<i>Type of work</i>	<i>Unit of measurement</i>
Sinking test pits	Linear foot of depth
Removal of bushes, undergrowth, etc.	Lump sum or acre

<i>Type of work</i>	<i>Unit of measurement</i>
Removal of trees and tree stumps	Enumerated, in various stages
Demolition work	Lump sum
General excavation	Cubic yard
Excavation of pipe trenches	Linear yard, in various stages
Excavation of top soil and stripping turf	Square yard ('extra over')
Trimming slopes, and soiling and seeding or turfing	Square yard
Dredging	Cubic yard
Pitching to slopes	Square yard
Mass concrete	Cubic yard
Mass concrete in slabs, roofs and floors, not exceeding 12 in. thick	Square yard or cubic yard
Reinforced concrete	Mainly cubic foot or cubic yard
Shuttering	Mainly square yard
Bar or rod reinforcement	Cwt or ton
Fabric reinforcement	Square yard
Heavy precast concrete blockwork	Cubic yard, with certain particulars
Precast concrete members	Linear foot, cubic foot or number
General brickwork, up to 27 in. thick	Square yard
General brickwork, exceeding 27 in. thick.	Cubic yard
Facings and fair faced work	Square yard ('extra over')
Chases, corbels, etc. in brickwork	Linear yard ('extra over')
Rubble masonry	Cubic yard
Facework to rubble masonry	Square yard ('extra over')
Ashlar and dressed stone	Cubic foot
Cramps, dowels and plugs to masonry	Number
Asphalt work	Square yard
Asphalt skirtings and angle fillets	Linear foot
Asphalt lining to small sumps	Number
Concrete piles	Cubic foot
Cutting off or stripping heads of concrete piles	Number
Shoes to concrete or timber piles	Number
Handling and pitching piles	Number
Driving piles	Number or linear foot of penetration
Cutting off tops and ringing timber piles	Number
Steel sheet piling	Square foot
Corner and junction piles	Linear foot ('extra over')
Cutting or burning through sheet piling	Linear foot
Timber in constructional members and decking	Cubic foot
Timber handrails, guardrails, etc.	Linear foot
Steel or wrought iron straps, plates, bolts, etc.	Number
General steelwork	Ton or cwt for small quantities

Note: The rules for the measurement of building work are not considered in this book because they are extremely complex, and this class of work is almost invariably entrusted to quantity surveyors.

The first stage in preparing a bill of quantities is to 'take-off' the dimensions by scaling or reading them from drawings, and entering them in a logical order on specially ruled paper called 'dimension paper', as illustrated below.

Each dimension sheet is split into two identically ruled parts, each consisting of four columns, the purpose of which is now described.

Column 1 is termed the 'timesing column' in which multiplying figures are entered when there is more than one of the particular item being measured.

C.V.	SEWERAGE	SEWERS			
		<u>M.H.s 1-2.</u>	3/	1	E.O. tr. excavn. for 9" sewer for passg. under hedge. (M.H.s 1-3).
	<u>30.0</u>	Exc. in roadside verge for 9" sewer 10'-15' dp. (av. 11'-6" dp.), backfill & c.a. surplus, incl. reinstatmt. of surf.		1	Ditto. for passg. under ditch.
		225.0		296.6	
		less 50.0		236.6	9" s. & s. conc. pipe sewer, laid & jtd. in c.m. (1:2)
	<u>175.0</u>	<u>175.0</u>			(M.H.s. 1-3)
	<u>20.0</u>	Ditto. in field.			
		Ditto. in road (breakg. up & reinstatmt. of tarmac m/s).	2/	1	Exc. for cut to 9" conc. sewer.
	<u>70.0</u>	Exc. in field for 9" sewer, 5'-10' dp., (av. 9' dp.), do.		30.0	Conc. class "C" in 6" bed to 9" pipe (Provnl.)
		<u>M.H.s 2-3</u>			
	<u>235.0</u>	Ditto. (av. 8'-6" dp.), do.		296.6	
	<u>20.0</u>	E.O. excavn. for 9" sewer for breakg. up & perm. reinstatmt. of tarmac carriageway over line of tr. (M.H.s. 1-2).		236.6	water test 9" conc. pipes, as spec.
	<u>1</u>	E.O. tr. excavn. for 9" sewer for passg. under thr. fence. (M.H.s 1-2) (35)	The follg. in 3 no. precast conc. tube manholes.		
					Intt. dia. 3.6
					add walls
					2/ .9 1.6
					<u>5.0</u>
					depth
					6.6
					7.4
					8.2
					add bases
					22.0
					3/ .7 1.9
					<u>23.9</u>

FIG. 72. Entries on dimension sheet.

Column 2 is termed the 'dimension column' in which the actual dimensions, as scaled or taken direct from the drawings, are entered. There may be one, two or three lines of dimensions in an item depending on whether it is lineal, square or cubic. The order of dimensions should always be that of length; breadth or width; and height or depth.

Column 3 is termed the 'squaring column' in which the length, area or volume obtained by multiplying together the figures in columns 1 and 2 is recorded, ready for transfer to the abstract or bill.

Column 4 is known as the 'description column', in which the written description of each item is entered, the right-hand side of this wider column is frequently used to accommodate preliminary calculations and other basic information needed in building-up dimensions and references to the location of work, and is referred to as 'waste'.

Fig. 72 illustrates some typical entries on a dimension sheet. It will be noted that extensive abbreviations are used at the 'taking-off' stage and lists of commonly used abbreviations can be found in the books on quantities (13 and 14).

Abstracting

The squared dimensions need reducing to the recognised units of measurement (e.g. sq. ft to sq. yd) and sorting into the correct order for billing. In building work an abstract is often used for this purpose and consists of a double foolscap-sized sheet, divided into 1 in. wide vertical columns. In civil engineering work, the reducing is often performed on the dimension sheets and the quantities then transferred direct to the bill. Another alternative is the use of the system known as 'cut and shuffle' or the feeding of coded dimension sheets into an electronic digital computer, which produces a completed bill in a very short period of time.

Billing

The final stage in the preparation of a bill of quantities is the setting down of the billed descriptions and quantities on billing paper, as illustrated in the following example, ready for pricing by contractors. No abbreviations are permitted in the billed descriptions.

The billed items are usually numbered consecutively for ease of reference. The use of fractional quantities is avoided, unless the omission of the fraction affects the total amount of the item by more than, say, £1.

Item No.	Description	Qty.	Unit	Rate	£	s.	d.
	<i>Excavation</i>						
1.	Excavate below low water level for sea wall, not exceeding 30 ft deep, backfill as necessary and cart away surplus excavated material from the site.	1039	cu. yd				
2.	Ditto. between tides, not exceeding 20 ft deep and do.	405	cu. yd				
3.	Ditto, above high water level, not exceeding 10 ft deep and do.	136	cu. yd				
4.	Extra over general excavation below low water level for any additional excavation and backfill required for timbering or working space (area of sides of excavation measured).	430	sq. yd				
5.	Ditto, between tides for do.	178	sq. yd				
6.	Ditto., above high water level for do.	111	sq. yd				
	To Summary or Collection						
	(depending on whether or not the measurement of the section is complete).						

Where 'prime cost' sums are entered in the bill to cover the cost of materials to be supplied or work to be done by subcontractors, the main contractor must be given the opportunity of adding sums for profit and for fixing of materials or attendance on subcontractors. General provisional sums are frequently included in bills of quantities to cover contingencies and additional works that may arise during the course of the contract, due to site conditions or changes in design.

ESTIMATES

Municipal engineers are frequently required to prepare estimates of cost of projects for consideration by the appropriate committee, often before detailed schemes are prepared. It is essential that all estimates should be as realistic as possible and they require considerable care and

skill in their preparation. The preparation of annual estimates is dealt with in Chapter XIV.

The actual prices submitted by contractors at the tender stage will be influenced by many factors, including those listed below, and the engineer should endeavour to make allowance for them in his price:

- (1) Size of the job.
- (2) Site conditions and location.
- (3) Quality of finish likely to be expected.
- (4) Extent to which contractors in the area are already committed to work.
- (5) Availability of labour and materials in the area.
- (6) Time of the year when the work is to be undertaken.
- (7) Amount of information given to tenderers.
- (8) Time allowed for tendering.
- (9) Time allowed for execution of the work.

When preparing an estimate the average billed rates for previous jobs of a similar character are often used, suitably adjusted for period, site and constructional differences. Where suitable rates are not available it is usually necessary to build up rates from first principles. With building projects, various methods of approximate estimating are sometimes employed, such as the unit, cube, super, storey-enclosure and rough quantities methods, in cases where considerable knowledge of past costs of similar projects is available. Short cuts can sometimes be taken with civil engineering projects, for instance where tabulated lists have been prepared giving unit costs of various items of completed constructional work; for example, the price per linear yard of a 12-in. British Standard clayware sewer, jointed in cement mortar and laid on a 6-in. concrete bed, in a trench of an average depth of 6 ft (including excavation). A selection of prices for manholes would cover different forms of construction, sizes and depths.

The prices of most items of constructional work are built up from four main components:

- (1) Labour—craftsmen and labourer's time, sometimes including insurances, graduated pension payments, selective employment tax and holidays with pay contributions, to give all-in hourly rates.
- (2) Materials, including waste, transportation, unloading and handling at site.
- (3) Plant—either owned or hired and calculated on an hourly basis, including operator and fuel.
- (4) Overheads and profit—often expressed as a percentage of the sum

of the previous three items (a typical figure might be in the order of 20 per cent). Overheads represent all incidental items connected with the execution of constructional work, such as office and supervisory staff; office, workshop and yard expenses; etc.

The amount of labour needed to perform a given unit of work is referred to as a 'labour constant' and most estimating and price books contain many hundreds of such constants. In practice labour constants or outputs should be worked up from the analyses of the actual performances on past jobs, with allowance made for any differences in the work under consideration. When estimating, care must be taken to allow for such items as the increase in bulk of soil on excavation, loss of hardcore on consolidation, loss of concrete in shrinkage, waste and consolidation, etc., as they all have an important effect on price.

Readers requiring further information on estimating are referred to the books listed in reference 15. A relatively simple price build-up follows to illustrate the method of approach:

9-in. brickwork in common bricks in cement mortar (1:3) per square yard

	s.	d.
100 common bricks (including 4 waste) @ 150/- per thousand	15	0
2 cu ft of cement mortar @ 3/-	6	0
Unloading bricks: Labourer $\frac{1}{10}$ hr @ 6/3		7 $\frac{1}{2}$
Laying bricks: Bricklayer—2 hrs @ 7/-	14	0
Labourer—1 hr @ 6/3	6	3
	41	10 $\frac{1}{2}$
Add Establishment Charges and Profit (say, 20 per cent)	8	4 $\frac{1}{2}$
Cost per Square Yard	50	3

(Note: the prices of materials and labour rates are fluctuating continually)

COST PLANNING

In building work it has been found highly desirable to maintain cost control during the design stage of a job, to keep the total cost within the employer's requirements. A substantial increase in cost over and above the initial estimated figure could mean that the project will become unacceptable to the local authority (the employer).

It is customary for a quantity surveyor to prepare a cost plan at an early stage, in which the proposed expenditure on each element of the

building is listed in terms of cost per ft² of floor area of the building. Cost checks are made throughout the design process, to check that probable costs do not exceed estimated costs, and making suitable adjustments to the design and/or the cost plan where necessary. When comparing alternative designs, consideration should be given to running and maintenance costs (adjusted to give a present-day lump sum figure covering the life of the building) in addition to initial constructional costs. Cost planning thus aims at securing the best value for money and the distribution of the available funds in a balanced and logical manner throughout the scheme, in addition to keeping within the initial estimate.

There seems little doubt that the basic principles of cost planning could be equally well applied to civil engineering work, and that when alternative forms of construction are considered, maintenance costs over the life of the scheme should be compared as well as initial constructional costs. Consideration should also be given to possible methods of reducing constructional costs, as by designing reinforced concrete structures to permit the optimum use of shuttering. Readers requiring further information on cost planning methods, as applied to building work, are referred to the publications listed in reference 16.

TENDERING PROCEDURE

Tenders for municipal engineering works are usually invited by one of three methods:

- (1) By advertising for competitive tenders.
- (2) By inviting tenders from selected contractors.
- (3) By negotiating a contract with a selected contractor.

Advertisement for competitive tenders ensures maximum competition, but it has the grave disadvantage that tenders may be received from contractors who have neither the necessary financial resources nor adequate technical knowledge and experience of the class of work involved. In the past the majority of municipal engineering contracts have been dealt with in this way.

When tenders are invited from a selected list of contractors the principal disadvantage of open competition is removed. The Ministry of Housing and Local Government issued revised model standing orders to local authorities in 1964, to facilitate the wider use of selective tendering procedures as favoured by the Banwell Report (3). In 1965, the Ministry gave guidance to local authorities on the operation of selective tendering

procedures, including the use of a standing approved list and *ad hoc* approved lists for individual contracts (17). The number of contractors invited to tender for a job usually varies with the size of the contract, from say 4 firms for contracts below £500 in value, to 12 firms for contracts exceeding £200,000.

Negotiation of a tender with a selected contractor is only advisable in special circumstances, as it entirely eliminates any element of competition. This procedure might be usefully adopted when it is required to make an early start with the work, where the contractor has exceptional experience of the specialised work contained in the contract or where an extension to a contract secured with a keen tender under methods (1) or (2) is involved.

Tenderers are usually supplied with a copy of the specification, site plan and other essential drawings, and often two copies of the bill of quantities (one only to be returned). A full set of contract drawings is made available for inspection at the offices of the local authority during normal office hours. Contractors should be given a minimum period of 21 days to submit tenders, after receipt of tender documents.

EXAMINATION OF PRICED BILLS

After the opening of tenders, often by a committee chairman, the priced bills of quantities will be examined to ensure that the pricing is arithmetically correct and that there have been no obvious errors in assessing the billed rates, such as the insertion of a linear foot price against an item billed in linear yards. Entries in the basic schedules of prices, contract periods when determined by the contractor and any conditions in letters accompanying tenders all deserve careful scrutiny.

Where errors in pricing are found, the contractor concerned is usually notified and asked if he is prepared to stand by his tender figure. A percentage addition or reduction can then be applied to all the measured work prices to make allowance for the difference. On occasions, a substantial difference in contract period may outweigh a small reduction in the tender sum.

The engineer will submit a list of tenders received to the appropriate committee, giving the names of tenderers, tender figures, contract periods and any other relevant information, together with recommendations relating to the award of the contract. The committee's decision will often be subject to confirmation by the full Council and possibly a Government department, particularly where a loan is required. Once confirmation is received the successful contractor should be notified as soon as

possible, and the remaining contractors should be supplied with a list of the tender figures received, possibly without the names of contractors.

SITE ORGANISATION

Duties of Resident Engineer

On the larger contracts a resident engineer will be employed full-time on the site, and the engineer for the contract (the local authority engineer or consultant) should notify the contractor in writing of this appointment, and give details of any powers that have been delegated to him. With small contracts the supervision is normally undertaken by an assistant engineer operating from the municipal offices, preferably the person who prepared the scheme. The resident engineer will, on behalf of the engineer for the contract, issue instructions and drawings to the contractor's agent. The contractor's agent is the chief executive in control of the contractor's site organisation, and is usually an experienced engineer who makes many of the day-to-day decisions on the site.

The resident engineer is usually supported by a staff of inspectors, and possibly clerks and engineers on a very large contract. Inspectors must have extensive knowledge of modern practice relating to the work or trade which they have to supervise. The principal duties of a resident engineer are as follows:

- (1) Organisation and phasing of the duties of his staff to effectively cover the constructional programme submitted by the contractor.
- (2) Supervision of the permanent work to ensure that it is of the correct dimensions and to the proper lines and levels, and that the materials and workmanship comply with the specification.
- (3) Execution or supervision of site tests, and possibly the inspection of materials and manufactured articles at source.
- (4) Keeping a diary and submission of progress reports to the engineer for the contract at regular intervals, usually monthly.
- (5) Measuring, with the contractor's staff, the quantities of work executed and checking daywork, other accounts and increased cost vouchers, prior to certifying payments to the contractor. The measurement aspects may possibly be dealt with by a quantity surveyor. Daywork is usually valued in accordance with a daywork schedule incorporated in the bill of quantities, or on the basis of the schedules of dayworks carried out incidental to contract work (18).

- (6) Agreeing with the contractor the details of any work where the contractor may claim payment for additional work.
- (7) Recording and checking the progress of work as compared with the programme.
- (8) Examination of contractor's methods, including those for temporary work, to ensure the safe and satisfactory execution of the permanent work.
- (9) Redesign of work and preparation of additional details as required by the engineer for the contract.
- (10) Recording upon suitable drawings, details and levels of foundations, nature of strata encountered and details of any deviations from working drawings (1).

Note: Inspection of works at the end of the maintenance period and the clearance of the maintenance defects may be undertaken by the resident engineer, or another engineer if he is not available.

Programme and Progress Charts

'Programming' is the breaking down of the contract works into a series of operations, which result in an orderly development by stages from the temporary and preliminary operations through to the completion of the permanent works. Without a programme the work is likely to be carried out in a haphazard and disorderly manner.

The contractor's programme shows the engineer the periods when the individual sections of work are to be carried out, and indicates the dates when detailed drawings will be required. It helps the contractor to plan his labour, materials and plant requirements throughout the contract. When the contract is under way regular progressing is adopted to see that the programme is followed as closely as possible, usually on the basis of the quantity of work done. Lack of progress will necessitate some modification of the programme.

A relatively simple programme and progress chart covering a small roadwork contract is illustrated in Fig. 73. The contract period is ten weeks and the chart indicates both the programme and progress at the end of the sixth week. Cumulative weekly quantities of work planned and actually executed are inserted for each of the three main sections of work. Each thick black line indicates the quantity of work completed and the hatched sections show the work still remaining to be done. The thin black line shows the period throughout which the particular operation has been performed.

The position at the end of the sixth week is that the excavation work was completed half a week behind schedule, the laying of granular base

is a week behind schedule but this presents no difficulties, and the concreting work is half a week behind schedule, but provided the present rate of output is maintained the job can be completed within the contract period. Programme charts usually contain far more items than the one illustrated; also there is usually a preliminary works item at the start and a clearing up item at the finish, possibly occupying a week each, and information on plant and labour requirements for each operation is frequently added. Further information on programming and progressing can be obtained from the Ministry publication on this subject (19). Some information on network analysis is given in Chapter XIV.

ROAD WORK CONTRACT										
WORK	WEEK 1	2	3	4	5	6	7	8	9	10
EXCAVATION 4000 C.Y.	500	1500	2500	3500	4000					
	200	1000	1800	2700	3700	4000				
GRANULAR BASE 8000 S.Y.		800	2500	3600	5200	6800	8000			
			800	2000	3600	5200				
CONCRETE SLAB 8000 S.Y.			1600	2400	3600	4800	6000	7200	8000	
			800	1800	3000	4200				

FIG. 73. Programme and progress chart.

Measurement of Contract Work

The resident engineer is usually responsible for measuring the work as executed and valuing it at billed rates, where they are applicable. Most of the measurement normally takes place at monthly intervals, prior to the issue of interim certificates certifying payment by the local authority to the contractor. Prior to measuring the engineer gives notice to the contractor, who may attend or send a qualified agent to assist the engineer or his representative in carrying out the measurements. If the contractor fails to send an agent, the measurements taken by the engineer are taken as the correct measurement of the work.

The engineer also has the power to fix rates for varied or substituted work, although he must fix reasonable rates. The contractor has the right to take any disputes over rates, or any other matters connected with the contract, to arbitration. All variations to the contract works should be the subject of numbered variation orders from the engineer to the

contractor, and the contractor cannot legally demand payment for varied work in the absence of a written variation order.

Measurements of executed work should always be systematically and neatly recorded in dimension books, with full descriptive notes as to location. A note should also be made of the date the measurements were taken and the name of the contractor's representative who attended the site measurement.

The certificate issued by the engineer includes the value of work executed, plus unfixed materials on the site, less sums already paid under previous certificates and retention money. Retention money, often amounting to 10 per cent of the sum due to the contractor up to a specified limit, is retained by the employer to ensure satisfactory completion of the work by the contractor. Half the retention money is normally released to the contractor on completion of the job, and the other half on satisfactory rectification of maintenance defects at the end of the maintenance period.

An example of a typical interim certificate follows:

30th March, 19—
Instalment No. 8

Job No. SDW/1
To the Seaport County Borough Council:

I hereby certify that the sum of Sixteen Thousand Pounds (£16,000-0-0) is due to Messrs Civil Engineering Constructions Ltd. of Newtown, for work done and materials supplied on the sewage disposal works extension contract.

I. B. A. Sewerman
Borough Engineer

Previously certified	£105,000
Now certified	16,000
Total certified	£121,000
Contract sum:	£254,326-5-6

Note: The certificate will be supported by an interim valuation giving details of the measured work, daywork, unfixed materials, increased costs, etc. and also the deduction of retention money.

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CHAPTER FOURTEEN

Administration

THE final chapter in this book is concerned with the principal administrative aspects of a municipal engineer's department, including organisation of staff, work study, council and committee work, office procedure and the preparation of reports and annual estimates.

ORGANISATION OF STAFF

The engineer and surveyor to a local authority is the executive and administrative head of his department, and is responsible for all actions taken by his staff. It is the normal practice for all communications and decisions to be made in his name, and this appears on departmental notepaper, contract documents, plant, etc. There is, however, a strong case for more general recognition of the duties performed by individual assistant engineers.

The National Conditions of Service state that 'the first duty of a local government officer is to give his undivided allegiance to the authority employing him'. Undoubtedly loyalty, integrity and a high standard of professional skill are the basic requirements of the technical staff of a municipal engineer's department.

The staff of a municipal engineer's department can be broadly subdivided into three main categories—technical, clerical and outside staff. The technical staff of all but the smallest local authorities is usually further subdivided on a sectional basis. Technical staff becomes increasingly specialised as municipal engineering work assumes greater complexity and new developments and techniques are introduced. The principal sections in a large county borough might be: highways, traffic control, main drainage, parks and open spaces, central area redevelopment.

ment, building control, cleansing services and building maintenance. Town planning, architectural work and housing management will probably be undertaken by other sections, each with its own chief officer, but a high degree of co-ordination between these departments and that of the municipal engineer is vital.

Within each section of the municipal engineer's department there will usually be at least one principal or senior assistant engineer, supported by a number of assistant engineers and draughtsmen or technicians. In the future, technicians will be used to an increasing extent to carry out plan preparation and other ancillary functions, and so release the qualified engineers for design and other work requiring greater skills. The technical staff of each section will normally prepare drawings and other contract documents for new work and alterations to existing services, and generally maintain the services coming within their sphere of influence.

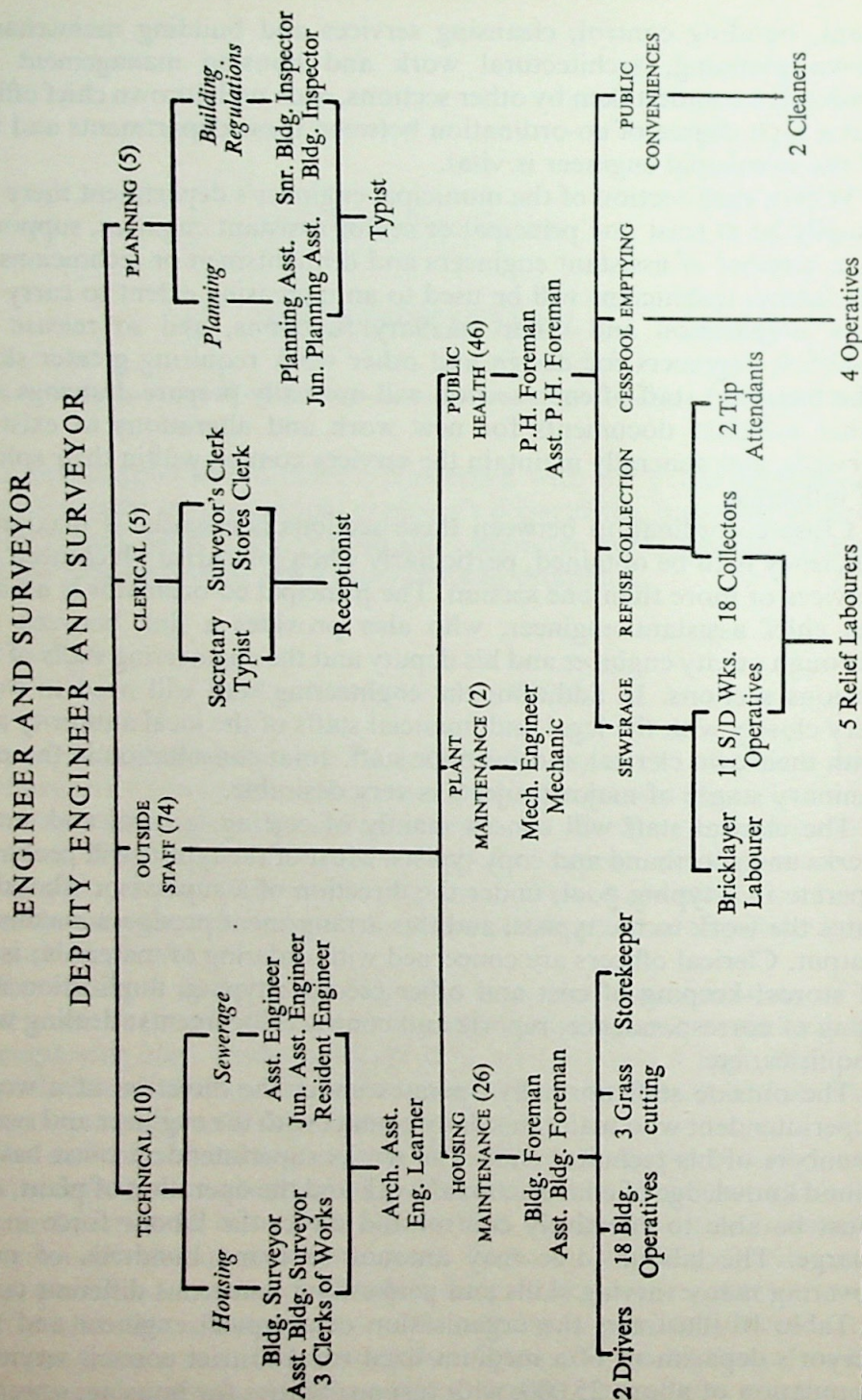
Close co-ordination between these sections is essential if maximum efficiency is to be obtained, particularly when jobs arise which need the services of more than one section. The principal co-ordinator is usually the chief assistant engineer, who also provides a link between the borough or city engineer and his deputy and the engineering staffs of the various sections. In addition, the engineering staff will need to work very closely with the legal and financial staffs of the local authority and with their own clerical and outdoor staff. Joint consultation in the preliminary stages of major projects is very desirable.

The clerical staff will consist mainly of costing, general and stores clerks and shorthand and copy typists. Most of the typists will probably operate in a typing pool, under the direction of a supervisor who allocates the work to the typists, and this arrangement produces maximum output. Clerical officers are concerned with ordering of materials; issue of stores; keeping of cost and other records; typing, duplication and filing of correspondence, reports and contract documents; dealing with enquiries; etc.

The outside staff normally operates under the direction of a works superintendent who maintains daily contact with the engineer and senior members of his technical staff. The works superintendent must have a sound knowledge of constructional work and the operation of plant, and must be able to effectively control and direct the labour force in his charge. The labour force may amount to many hundreds of men, covering many varying skills and performing numerous different tasks.

Table 16 illustrates the organisation of a typical engineer and surveyor's department of a medium-sized rural district council serving a population of about 25,000, with responsibilities for housing, sewerage

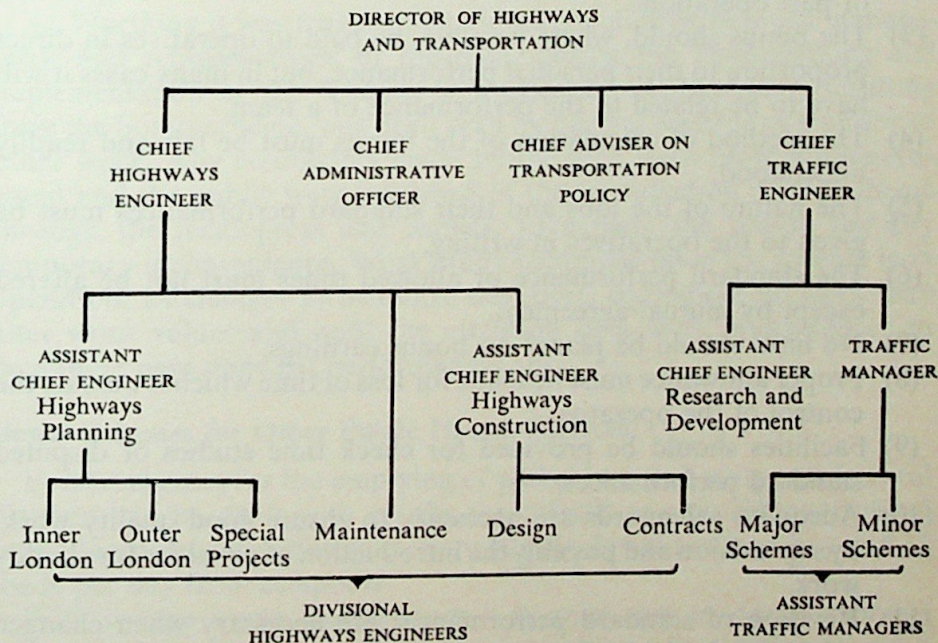
TABLE 16. ORGANISATION OF THE ENGINEER AND SURVEYOR'S DEPARTMENT OF A RURAL DISTRICT COUNCIL



and sewage disposal works, refuse collection, cesspool emptying, administration of building regulations and some delegated planning powers.

By way of comparison, Table 17 shows the proposed organisation of the highways and transportation department of the Greater London Council. This department is responsible for research into and development of a comprehensive transportation scheme for an area of 600 miles² and 8 million population; planning the future road system, including urban motorways; design and construction of the main thoroughfares and intersections; and traffic management schemes throughout the metropolis.

TABLE 17. ORGANISATION OF THE HIGHWAYS AND TRANSPORTATION DEPARTMENT OF THE GREATER LONDON COUNCIL



It is important that good relations should be maintained between the engineer to the authority and the engineering and outside staffs. There should be mutual confidence in one another and the aim to work as a team. Great difficulty is experienced by many authorities in recruiting workmen of the right calibre and this has resulted in the introduction of many incentive bonus schemes.

INCENTIVE BONUS SCHEMES

The purposes of incentive bonus schemes are twofold:

- (1) To increase productivity and to lower operating costs.
- (2) To help in recruiting additional personnel of the right calibre and to retain existing employees, under conditions of increasing competition from other sources of employment.

Requirements of Bonus Schemes

The following basic requirements must be observed if a bonus scheme is to operate satisfactorily:

- (1) The scheme must increase output and efficiency, in addition to giving larger earnings to the operatives.
- (2) The standard performances must be based on extensive work study of past operations.
- (3) The bonus should, where possible, be paid to operatives in direct proportion to their personal performance, but in many cases it will have to be related to the performance of a team.
- (4) The method of calculation of the bonus must be fair and readily understood.
- (5) The nature of the jobs and their standard performances must be given to the operatives in writing.
- (6) The standard performance or allowed times must not be altered except by mutual agreement.
- (7) No limit should be placed on bonus earnings.
- (8) Proper allowance must be made for loss of time which is outside the control of the operative.
- (9) Facilities should be provided for check time studies of disputed standard performances.
- (10) Adequate safeguards are necessary to ensure good quality work, by supervision and possibly the introduction of penalties for shoddy work.
- (11) Revision of standard performances are necessary when changed methods of working are introduced.
- (12) Bonus should be calculated weekly but payment will normally be one week in arrear.
- (13) The savings resulting from the bonus scheme must be distributed in a reasonable manner—a common distribution is 50 per cent to the operative and the remaining 50 per cent to the local authority to cover extra administrative costs and provide a contribution to the rates.

Bonus Schemes for Refuse Collection

Prior to the introduction of a bonus scheme it is necessary to carry out an investigation of the refuse collectors at work, for the purpose of establishing standard performance values on which to base the payment of bonus. At Worthing the observed collection rates averaged 21·6 bins per paid man-hour, and this rate is termed '100 performance' (see reference 1 at the end of this chapter).

The bonus payment is usually fixed at a fixed sum per bin or property above the standard performance. The standard performance will depend on many factors, such as the type of vehicle used, length of haul to tip, type of collection area, frequency of collection, method of collection and age and physical standards of the collectors. The standard performance figures can vary from about 100 to 160 bins per man-day. Bonus payments also vary considerably from about 1½d to 3½d per bin, and drivers should receive the same rate of bonus as the collectors.

At Worthing it was realised that close consultation between management and representatives of the men, during the investigations and implementation of the scheme, was essential. Redundancy, resulting from the bonus scheme, was dealt with by normal wastage or transfer to other work. Any complaints made by the men were promptly investigated and the public were informed of the introduction of the scheme through the local press and leaflets, to explain the reason for any temporary inconvenience. Work study continues once the scheme is in operation, as changes in methods, transport, equipment or work may alter work values and need the attention of a work study officer to determine new standard performances (1).

Bonus Schemes for Other Public Health Services

Bonus schemes for the emptying of pail closets and cesspools in rural districts can be dealt with on the same basis as refuse bins. Typical targets or standard performances are 50 pail closets per man-day and 12 loads per day from cesspools.

With sewage works maintenance it is quite easy to devise a bonus scheme based on previous output, but the problem of maintaining a good standard of work remains. The best solution is to make the payment of bonus dependent upon the maintenance of a clean works and a good effluent.

Bonus Schemes for Housing Maintenance

The best method of working seems to be that introduced at Middlesbrough in 1958, where by detailed observation and timing of the various

operations (work measurement) work values were established for each operation in each trade. These work values were calculated so that an experienced operative of average ability could achieve a performance of 133 (standard performance = 100). In all cases due allowance was made for the occurrence of minor interruptions, adequate rest for arduous work, attention to personal needs, travelling from depot to job and from job to job, obtaining gear from depot and replacing it at night and receiving instructions and drawing stores.

Half of each operative's bonus is based on his own personal performance, while the other half is based on the combined performance of all the operatives in his trade. This procedure balances out the advantages and disadvantages of various tasks. Each operative completes a weekly work sheet and records details of measured work done and any unmeasured work or lost time. Each operative has a work specification, which gives standard hour values (standard performances), scales of bonus payments and travelling and general allowances.

The jobs completed by an operative are multiplied by the appropriate standard hour value, to give the total credits for measured work done. Credits for unmeasured work and time lost are added to give the total weekly credit. Total credits of operatives are then equally divided: one half is retained and the other half goes into the pool with the corresponding contributions from other operatives of the same group. The pool total is divided between the operatives in proportion to their hours of work.

Table 18 illustrates the method of determining work values for repairing or renewing a mortise lock, based on observations carried out by Middlesbrough Borough Engineer's department.

TABLE 18. HOUSING MAINTENANCE: OPERATION VALUES FOR LOCKS

<i>Operation</i>	<i>Basic time in min (standard performance)</i>	<i>Occasional and contingency %</i>	<i>Rest allowance %</i>	<i>Standard minute values (S.M.V.)</i>
(1) Remove furniture and replace, where work done on lock	4.84	17	12	6.3
(2) Remove mortise lock and replace	9.34	17	12	12.2
(3) Inspect mortise lock and repair	6.58	17	12	8.6
(4) Alter mortice on door to receive different size mortise lock	12.17	17	12	15.9

The operation values are converted to job values by adjusting by the frequencies observed during work study. Table 19 shows how this is operated (for instance the frequency of repair of locks on this type of job is 4 times out of 9, whereas that of altering doors is 3 out of 9).

TABLE 19. HOUSING MAINTENANCE: JOB VALUES FOR LOCKS

<i>Operation</i>	<i>Operation S.M.V.</i>	<i>Frequency per lock</i>	<i>S.M.V.</i>
(1) Remove and replace or renew furniture	6.3	9/9	6.3
(2) Remove and replace or renew lock	12.2	9/9	12.2
(3) Repair lock	8.6	4/9	3.8
(4) Alter mortise	15.9	3/9	5.3
(5) Alter door	5.7	3/9	1.9
(6) Alter or fit new keep	11.3	6/9	7.5
(7) Ease closing edge	9.5	1/9	1.1
Total time for average job of mortise lock renewal or repair			38.1

Note: 38.1 S.M. (standard minutes) = 0.6 S.H. (standard hours).

Bonus Schemes for Other Services

Most highway jobs can be assessed on the basis of area or length of work performed per day. With grass cutting, the standard performance per day of each type of mower can be determined by work study and a bonus paid for any additional area that has been cut. The same method can be applied to the area of concrete slab laid, footway paved, carriage-way surface dressed or road surface swept, or the length of kerb laid. In most cases the standard performances will relate to gangs and not individual men.

Work study can often indicate more efficient methods of performing a given job. For this reason most larger authorities employ works study officers with the object of improving efficiency and increasing output. This technique is, however, more correctly termed method study: analysis and study of the existing methods of carrying out work to determine whether or not they can be improved. This often involves the preparation of flow process charts and multiple activity charts, to isolate the individual operations or activities and show their sequence (2). A useful book on work study is given in reference 3.

NETWORK ANALYSIS

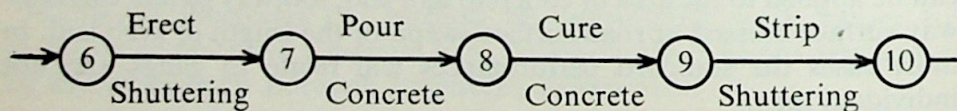
The need for greater efficiency and speedier completion of jobs calls for more thorough and skilful planning of projects, particularly those to

be carried out by direct labour forces. There are many planning systems based on network analysis methods, including the critical path method (C.P.M.). Furthermore, network analysis lends itself to rapid revision by computer.

The network is basically a project graph, which clearly depicts the various operations which have to be performed to complete a project and their inter-relationship. Each of these operations can often be carried out in a variety of different ways, by varying the amount of labour, number and size of gangs, working hours, plant employed, etc. The optimum combination should normally represent the lowest cost, subject to availability of plant and personnel, and this can be determined by network analysis.

Certain of the operations are critical, in that if they are delayed or prolonged the completion date of the job will be delayed also. Other operations can be delayed without affecting the completion of the job as a whole. Network analysis pinpoints the critical operations and enables the time leeway for all other operations to be determined.

Networks consist basically of circles, or sometimes squares or triangles, and lines or arrows. The circle is an event in the life of the project and is not time consuming, and represents the point at which one operation is completed or another can start. The line or arrow shows the direction of work flow. One operation has often to be completed before another can commence, as illustrated in the following example:



In this example the numbers represent events, e.g. shuttering fixed at 7 and concreting completed at 8, whereas the arrows denote the actual activities. Broken lines also appear on networks to indicate dummy activities, which have no value in time or resource usage but merely show interdependency. Some are illustrated in Fig. 74.

In drawing up a network three questions must be asked when considering each activity:

- (1) What activity must immediately precede this operation?
- (2) What activity can immediately follow this operation?
- (3) What activities can be taking place concurrently with this operation?

In the critical path method the time factor must be taken into consideration, and the estimated time for each activity is shown on the net-

work. Earliest event times can then be calculated and are often entered on the diagram in squares or circles, adjacent to the event numbers. Subsequently latest event times, which still permit the completion of subsequent events within the overall project time, are added. The critical path indicates the chain of critical activities along which any delay must prolong the project completion time, and this is usually indicated by a thick line.

The spare time or leeway available in activities off the critical path is termed 'float'. The total float is the difference between the latest finishing time and the earliest starting time, less the duration time for the activity.

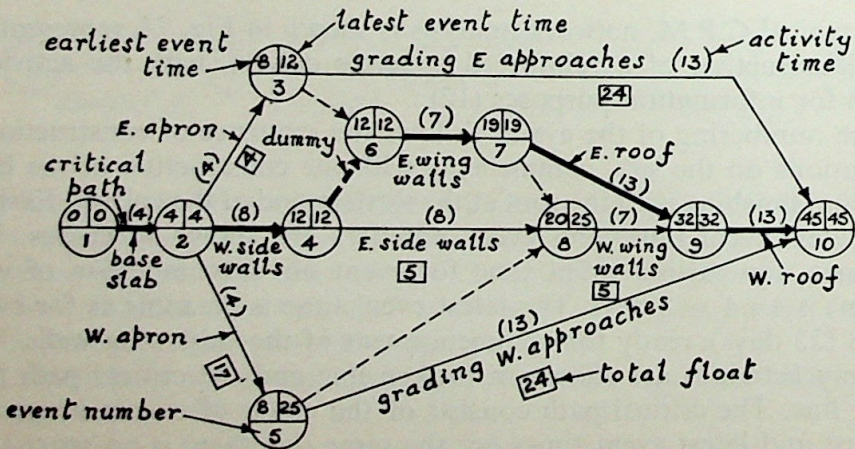
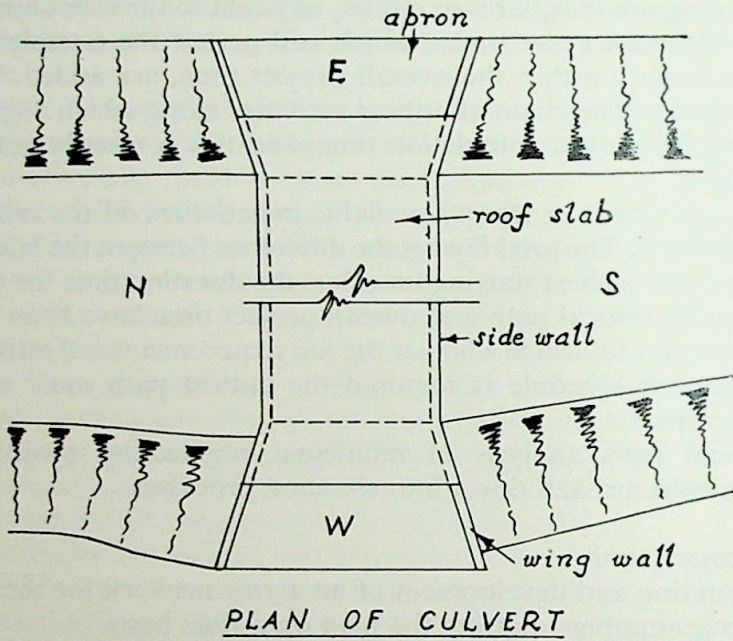
Once the critical path and overall project time have been established it is necessary to decide whether the job requirements are satisfied. When an improved schedule is required the critical path must receive first consideration.

Critical path analysis of municipal engineering projects can be conveniently broken down into six main processes:

- (1) Project study.
- (2) Planning and development of an arrow network for the project.
- (3) Programming—putting the plan on a time basis.
- (4) Determining project duration—critical path and floats.
- (5) Re-appraisal and possible revision of network and programme.
- (6) Preparation of programmes for management control purposes (4).

A typical C.P.M. network analysis is shown in Fig. 74, representing the construction of a reinforced concrete culvert, with the activities listed for information purposes (12).

The numbering of the events follows the sequence of constructional operations on the site, commencing with the construction of the base slab and finishing with the roof at the western end of the culvert. Earliest and latest event times and event numbers are shown in circles. For instance, the earliest event time for event no. 5 (completion of west apron) is $4 + 4 = 8$ days. The latest event time is the same as for event no. 8 (25 days), ready for commencement of the west wing walls. The dummy activities are shown in broken line and the critical path in a thick line. The critical path consists of the chain of events where the earliest and latest event times are the same (i.e. there is no spare time or float). The total constructional period of 45 days will have to be considered in relation to the programme for the job as a whole, and if this period proves excessive it will be necessary to review the constructional methods with a view to reducing the time required for the activities on the critical path.



CRITICAL PATH NETWORK FOR CULVERT

FIG. 74. Critical path method.

Floats may be of four different types:

(1) **Total Float** is the difference between the latest finishing time and the earliest starting time, less the duration time for that activity.

(2) **Shared Float** is common to more than one activity, and if used by one activity is no longer available to another; for example, activities 4 to 8 and 8 to 9, where a shared float of 5 days is available.

(3) **Independent Float** operates when an irreducible, but longer than necessary time is available for an activity; for example, activity 5 to 10, where the independent float = $45 - 25 - 13 = 7$ days.

(4) **Free Float** is the difference between the earliest finishing time and its succeeding earliest event time for any activity, as for example in activity 8 to 9, where the free float = $32 - 20 - 7 = 5$ days, and it cannot be used by succeeding activities.

It is customary to prepare a work schedule, indicating all the operations shown on the network analysis with their earliest and latest starting and finishing times, total, independent and free floats and critical path activities.

Readers requiring further information on the critical path method, are referred to the various Building Research Station publications (5), and a very useful paper on its application to the work of a county engineer's department (6).

Nottingham City engineer's department is using critical path networks and a computer for programming and progressing manpower, monetary and other requirements during the design stage of projects.

USE OF COMPUTERS

Computers are playing an ever-increasing part in municipal engineering activities. On the design side, electronic computers can be programmed to perform stress calculations, statistical correlations and analyses of all kinds. The calculating ability of the computer has resulted in new and improved methods being used for performing calculations, and the attainment of more economic and more complex structures and mechanisms. Further computer development has taken place in the fields of simulation and design automation.

Computers can play a valuable part in engineering data control systems in which the computer acts as a storehouse of data on a project and can

relate any new information to that which already exists. Comprehensive reports and exception lists can be easily and readily produced, and the organisation concerned has ready access to a file of complete, consistent, accurate and up-to-date information on any project (7).

Computers can also assist in the planning of projects and implementation of critical path techniques. A further use is in connection with the preparation of bills of quantities and estimation of earthwork and other quantities.

In the future the computer will doubtless be regarded by municipal engineers as a normal working tool. Various local authority and other organisations have computer programmes available in a variety of municipal engineering subjects. For instance, the County Surveyors' Society has programmes in roads, bridges and traffic engineering; the Greater London Council in engineering calculations and traffic engineering; and the London Boroughs in critical path analysis and costing procedures. A valuable paper on the operation and application of computers to design of sewerage systems is listed in reference 8, and two useful articles on the use of computers by municipal engineers are listed in references 13 and 14.

ADVERTISING FOR AND APPOINTING STAFF

The majority of municipal engineering appointments are widely advertised in the local press, the appropriate professional or technical journals, and sometimes in the national press. The advertisements should be carefully worded to give all the essential particulars required by intending applicants, yet be sufficiently concise to avoid unnecessary expenditure. Necessary particulars include the name of the authority, title of vacant post, salary scale, brief particulars of duties, qualifications required, and incidental information such as superannuation, car allowance and housing accommodation, where applicable.

Applicants may be required to prepare their own applications or to complete application forms. The latter procedure is generally the best as it facilitates the comparison of applications. Some authorities request two or three testimonials, but the more common and probably the better procedure is to ask for the names of two or three referees who can be approached by the employing authority if it is deemed necessary, but certainly not in the case of every applicant.

The majority of municipal engineering appointments are permanent posts included in the superannuation scheme, terminable only by periods of notice ranging from one month for assistants to three months

for chief officers. Appointments are invariably made in writing with the letter prepared by the engineer or clerk to the authority. Salaries above the minimum of the appropriate scale are paid in certain cases, and the conditions of appointment will be those issued by the National Joint Council.

Staff cars are provided by a few authorities, but the more usual practice is for technical staff to provide their own cars and be paid a recognised allowance, primarily based on the mileage travelled on official business. Car allowances can be on casual or essential users' scales, depending on the frequency of use of the car for the authority's work.

It is almost universal practice for local authorities to interview a selected number of applicants for each post prior to making an appointment. It is customary to select a short list of about three to six candidates who are invited to attend for interview at the local authority's expense. The interviewing committee may vary from the engineer and his chief clerk for a typist's post to an establishment or finance committee for a senior appointment. Smaller councils often turn out in full strength to make a chief officer appointment, while others delegate this function to the chairmen of committees.

The primary purpose of the interview is to determine the suitability of the candidates for the vacant post. A common procedure is to ask each candidate to give a brief account of his experience, to follow with questions by the interviewing committee and finally to invite the candidate to raise any queries that he may have.

ATTENDANCE AT COUNCIL AND COMMITTEE MEETINGS

The engineer and his deputy, and occasionally senior technical assistants, attend council meetings and meetings of committees which are responsible for services coming within the jurisdiction of the engineer. The main functions of an engineer at a committee meeting are to report on the operation of services, to submit proposals for new work and alterations and to generally advise on technical matters. The committee's decision is required on any matter involving principle or policy.

The best practice is for the engineer's written report to be circulated in advance with the agenda for the meeting. This procedure ensures that all committee members have ample opportunity to fully consider each item before it is discussed in committee, avoids snap decisions being made on matters raised without prior notice in committee and ensures that the official gives adequate consideration to his proposals. Engineers generally

consult with the main committee chairmen between meetings, particularly when urgent decisions are needed on emergency measures. Some authorities have set up works committees to control the letting of contracts and operation of constructional works of all kinds, using the argument that these matters are best handled by a single committee which can correlate experience in these fields and use that wider experience to deal with the problems that arise.

Sub-committees may also be appointed to deal with routine business or matters needing the attention of persons with special experience. A real danger with committees is that they tend to discuss far too much detail, which leads to delay and lack of decision on matters of importance.

In council meetings the reports are presented by committee chairmen, who usually answer any questions raised by other members, but the engineer is present to advise where necessary. In committee, the engineer should always aim at supplying information concisely and in non-technical language, as far as possible.

BYE-LAWS AND STANDING ORDERS

Bye-laws made by local authorities by virtue of various Acts of Parliament have the force of law within their sphere of operation. They are frequently based upon model bye-laws issued by the appropriate Ministry which assists in securing a reasonable degree of uniformity in their requirements.

Before they can become operative, a copy of the draft bye-laws is submitted to the appropriate Minister for examination and confirmation, and notice of the submission is inserted in the local press so that any representations can be made to the Minister.

Standing orders largely determine the constitution, terms of reference and extent of authority of committees and officers. They are often subject to annual review to make provision for any revisions made necessary by changed conditions. A common standing order relating to receipt of all tenders by open competition, which often created problems for the engineer, is now largely suspended.

SUBMISSION OF SCHEMES TO GOVERNMENT DEPARTMENTS

Local authorities frequently have to submit schemes to Ministries for approval, particularly where the jobs are grant-aided or where a loan

from the Public Works Loan Board is required to finance the scheme. In particular, the municipal engineer is often concerned with the submission of engineering schemes to the Ministry of Housing and Local Government.

For instance, details of a scheme for a new sewerage system or sewage disposal works would be submitted on Ministry form K29, giving details of loans required, any objections received, and stating whether any of the proposed works are outside the area of the submitting authority and whether planning and other consents have been obtained. The local authority also has to state whether any of the works will be below high water level, if land is to be purchased or leased and whether the works are to be carried out by contract or direct labour.

The engineer supplies an estimate on form K29, giving details of construction and cost of each length of sewer between manholes, and the cost of manholes, flushing tanks, ventilators and road reinstatement. The estimated cost of a sewage disposal works is broken down between the component parts with their capacities and the various items of machinery. The summary sheet includes provision for the cost of contingencies, engineer's fees, resident engineer, land costs, easements and legal and loan charges.

The engineer also submits a report setting out the need for the proposals, together with a description of the scheme and the calculations on which it is based. He also supplies signed maps and drawings illustrating the proposals, preferably in the form of prints on opaque linen with black lines on a white ground.

The engineer submits full design particulars of sewage disposal works on form Eng. 9. The particulars listed include the population, dry weather flow subdivided into domestic sewage, trade waste and subsoil water, character of sewage, flows, separation rates, etc. Details of the site are to be listed and full particulars of the type, capacity, number, rate of flow, etc. of each section of the works, together with various water levels. Details of existing works are entered in black and new proposals in red.

An inspector of the Ministry of Housing and Local Government investigates the scheme and visits the site. A public inquiry on the lines described in Chapter X may be held, particularly if there are objections to the proposals. The inspector reports to the Minister, who in due course communicates his decision to the local authority.

Where it is necessary to acquire land or buildings in order to implement proposals, these will be valued by the district valuer. The district valuer is a government officer, and he also acts as valuation officer for the same area. In the latter capacity, he fixes the rating assessments of all

hereditaments and deals with appeals to assessments on valuation lists, through local valuation courts and the lands tribunal, where necessary.

ANNUAL ESTIMATES

The preparation of annual estimates of work to be carried out in the next financial year (1st April to 31st March) forms one of the municipal engineer's most important duties. These estimates are normally prepared in about January of each year, ready for final approval by the council towards the end of March, when the new rate in the pound will be determined.

The engineer will be concerned with the probable cost of all works which it is proposed should be carried out in the next financial year, together with the running or operating costs of all the services under his control. For comparison purposes, annual estimates normally show the figures included for each item of expenditure in the current year's estimates and the probable expenditure based on actual costs up to the 31st December, plus an estimate of expenditure for the last quarter of the year. Typical column headings follow:

HIGHWAYS ESTIMATES 1967/68

Description of Work of Service	Est. 1966/67	Prob. Exp. 1966/67	Est. 1967/68	Increase	Decrease

Note: The last two columns show the increase or decrease of the estimate for the next financial year over that of the current year.

Annual estimates are submitted to each committee for the services for which it is responsible. The following list is a guide to the possible subdivision of estimates, but it varies considerably in practice from one authority to another.

Highways Committee—roads, footways, snow clearance, street lighting, etc.

Parks Committee—parks, gardens, playing fields, swimming baths, etc.

Public Health Committee—sewerage, sewage disposal, refuse collection and disposal, etc.

Cemetery Committee—cemetery maintenance and improvements.

Water Committee—water supply, purification and distribution.

Housing Committee—new housing and maintenance and improvement of existing dwellings.

Allotments Committee—allotments maintenance and improvements.

Each set of committee estimates will be further subdivided into various separate classes of work. For instance, highways estimates may be split into new roads and footways, road and footway improvements (classified and unclassified), road and footway maintenance (classified and unclassified), street cleansing, gulley cleansing, snow clearance, street lighting—new proposals and operation of existing facilities, etc. Roadwork proposals are normally detailed on a separate schedule and the totals transferred to the estimates. It is good policy for the highways committee, or a sub-committee, to inspect the roads listed on the detailed schedule prior to the meeting at which the highways estimates are considered.

Estimates for snow clearance normally allow for moderate falls of snow and are in the nature of a provisional sum. Gulley emptying is normally undertaken four times a year and the frequency of street cleansing depends upon the location and use of the street. Street lighting estimates will include the provision of new lamps, the replacement or conversion of existing lamps and the running costs involved. Lamp maintenance and power costs can amount to about £5 per lamp per annum, a very costly item when it is appreciated that there are hundreds of street lights in a small town.

Parks and open spaces estimates mainly consist of labour and machine costs in grass cutting and gardening work. Some provision will, however, be needed for new trees, shrubs and seats and the maintenance of paths, walls, small buildings, etc.

Housing maintenance estimates will include the cost of repairs and replacements, painting, provision of dustbins, lighting of communal staircase to flats, maintenance of amenity open spaces, etc.

In building up direct labour estimates, consideration must be given to the amount of labour, materials and plant required for each item of work. When calculating labour costs it is customary to take 52 weeks basic wages for each man and then to add a percentage to cover insurances, graduated pension contributions, sickness, holidays, protective

clothing, supervision, etc., when arriving at the effective weekly or yearly labour rate.

ANNUAL TENDERS

It is common practice to invite annual tenders for a wide range of high-way and other materials and components. Advertisements are normally inserted in local newspapers and technical journals; and forms of tender, with tendering conditions, are forwarded to all interested suppliers. The lowest tender received for each material or component is generally listed and approved and the supplier is duly notified and all orders throughout the coming financial year are placed with him. It is good practice to give the probable approximate required quantity of each item in the tender particulars and to notify all unsuccessful tenderers.

REPORTS

General Requirements of Reports

The municipal engineer is frequently required to prepare reports on technical matters for consideration by committees. These reports should contain a number of basic characteristics, which are now detailed:

Accuracy—avoidance of errors or vague statements, which can reflect adversely upon the engineer's ability.

Simplicity—freedom from technical terms, as far as possible, as the reports are usually prepared for consideration by laymen.

Clarity—contents easily read and understood, with ample sub-headings and the avoidance of long paragraphs and sentences.

Systematic Approach—a good order of presentation and the report broken down into following main sections where possible:

- (a) Introduction.
- (b) Main body of report, including a detailed description of existing conditions, where appropriate.
- (c) Conclusions and recommendations, including an estimate of cost where appropriate.

Continuity—the report should read logically from one paragraph to the next and lead up to the conclusions and recommendations.

Concise and Complete—the report must cover all relevant matters but be free from superfluous details.

Correct Grammar and Spelling—the contents of the report should be grammatically correct and free from spelling mistakes, which can create a bad impression.

Committee Reports

The most common reports prepared by the engineer are the routine reports for consideration by committees. These vary tremendously in their form and content, but the following short extract from a typical report to a planning committee may serve to illustrate one method of approach:

BLANKTOWN BOROUGH COUNCIL
PLANNING COMMITTEE, 8TH JULY 19--
BOROUGH ENGINEER'S REPORT

1. APPLICATIONS FOR DECISION

The following applications have been received and are submitted for the committee's decision:

PA/654/67 BATH AVENUE—Erection of bungalow for P. Smith Esq.,
24/6/67 65, Ryecroft Drive, Haverfield.

(reference RECOMMENDED that permission be granted subject to the
and date) following conditions:

- (1) The access to be constructed, laid out and maintained to the approval of the Borough Engineer.
- (2) The proposed bungalow shall not be occupied until the applicant has complied with the access requirements.

The reasons for these conditions are:

- (1) To minimise danger, obstruction and inconvenience to users of the highway and of the premises.
- (2) To ensure that a satisfactory means of access is provided at the time the development is carried out, and is satisfactorily maintained thereafter.

The report would then continue with the remainder of the planning

applications, followed by other planning matters, such as advertisement control, appeals, and building and tree preservation orders.

Other Reports

The engineer may be called upon to prepare reports on a wide range of matters, such as staffing, provision of open spaces, road improvements, alleviation of flooding, organisation and method studies by outside consultants and many other topics.

Typical headings for a staffing report could be: present duties of department, future duties of department, details of present staff, suggested regradings, work at present in arrear, additional staff requirements and recommendations. A report covering the flooding of part of a town might be subdivided into the following sections: extent of flooding, main causes of flooding, work undertaken by the local authority staff, work undertaken by other organisations, contamination of water supply and conclusions and recommendations.

PROOFS OF EVIDENCE

A proof of evidence is a form of technical report which is prepared by a municipal engineer when he is required to attend public inquiries, arbitrations or court proceedings, to give evidence on technical matters in dispute as an expert witness.

At the hearing the engineer will read from his proof of evidence and will later be cross-examined by the lawyer or counsel appearing for the opposing party. He must prepare his proof of evidence extremely carefully and the contents must be accurate and precise. The engineer must thoroughly investigate all the points at issue and be able to successfully withstand cross-examination by the opposing party's representative.

The proof of evidence will contain the name, official position, qualifications and broad details of the experience of the engineer. It will also give details of the investigations made by him, his findings on the matters in dispute and a summary of his conclusions.

CORRESPONDENCE AND FILING

Municipal engineers are involved in a large amount of correspondence with the public, elected representatives, Government departments, statutory undertakers, other local authorities, etc. It is essential that all

correspondence emanating from the engineer shall be clear, concise, free from errors, and be suitably referenced, headed and dated.

All letters from the engineer's department should be regarded as business letters, commencing with the words 'Dear Sir(s)' and terminating with 'Yours faithfully'. The use of actual names and such expressions as 'Yours truly' and 'Yours sincerely' are generally inappropriate. The name and address of the addressee should appear at either the top or bottom left-hand corner of the letter.

At least one carbon copy of each outgoing letter should be made for inclusion on the appropriate file and further copies may be required for insertion in letter books, or for passing to other officers of the authority for information purposes.

A typical letter to a member of the public follows to illustrate a method of presentation and general approach and showing sympathy and consideration, and this may prove useful to students.

Your ref: GOL/ABS

Our ref: R/4/20/BE

18th September, 19—

Dear Sir,

Improvement of Hazel Grove

I thank you for your letter of the 16th September, concerning the condition of the road surface in Hazel Grove.

I fully appreciate your concern at the bad state of the road surface, which urgently needs extensive repairs. Unfortunately the Council were unable to include the work in this year's programme, as there were insufficient funds available. My proposals for next year's highways programme will include making up the hollows in the carriageway surface and the application of a carpet coat of asphalt. I am optimistic that these proposals will be accepted by the Council.

In the meantime, I am arranging for the pothole outside your house to be filled as soon as possible.

Yours faithfully,
B. A. Highwayman
Borough Engineer

G. O. Lovejoy, Esq.,
14, Hazel Grove,
Blanktown.

The engineer or his deputy normally reads outgoing letters and signs them towards the end of each day. Letters written by assistants are generally checked and initialled by them, prior to being passed to the

engineer for signature, and the references of these letters will probably include the initials of the assistants concerned.

Copies of letters are filed as quickly as possible, with the most recent letters placed uppermost. Some filing systems introduce different colour tabs for different sections of work, such as green for highways files and yellow for sewerage files, etc., for ease of identification. The file references may be a combination of letters and numbers or merely numbers, and all persons writing letters should have access to a file index. Steel filing cabinets are almost invariably used.

Some municipal engineers' departments keep letter books, in which a copy of each outgoing letter is filed. Each letter is filed in date order and given a number, and an alphabetical index is prepared in which the name and address of the addressee is entered together with the number of the letter. This system has been condemned in some recent organisation and method reviews on grounds of unnecessary expense and extremely limited use. The need for a letter book system is limited where an efficient filing system is in use, although it is extremely useful for locating letters which could be filed under a number of different headings or file references.

It is important that all council and committee decisions should be conveyed to the persons concerned as speedily as possible. It is good policy to prepare all letters, and approval and disapproval notices prior to a council meeting, so that signatures only are required after the meeting and they can be dispatched with a minimum of delay. Agendas, minutes of meetings, reports, estimates, etc. are normally stencilled and duplicated, as a considerable number are required in each case.

GENERAL OFFICE ROUTINE

The general office of an engineer's department must operate efficiently and give good service to the public. Members of the public visiting the general office must receive prompt and considerate attention, and ample and comfortable waiting accommodation should be provided. Proper provision must be made for the receipt of telephone messages for officials away from the office.

All persons writing to the engineer should desirably receive a reply or an acknowledgement card within three days of receipt of the letter.

Invoices for the supply of materials and components and for work done need careful and prompt scrutiny. A cash discount of $2\frac{1}{2}$ per cent is normally deducted, although payment of the invoice should then be

made within 30 days of its receipt. Most local authorities have comptometers or adding machines for carrying out arithmetical processes.

The accounts of many local authorities are subject to district audit. The district auditor is a person appointed, by the Ministry of Housing and Local Government, to ascertain that all income received has been duly accounted for and that everything stated to have been spent has been expended, and to determine whether the expenditure is truly stated and has been made in conformity with the law. He may summon before him any person liable to account and may require the production of any necessary books and documents. The district auditor has a duty to disallow every item of account which is contrary to law, and to surcharge the amount of any expenditure disallowed upon the person responsible for incurring or authorising the expenditure.

RECORDING OF INFORMATION

It is important that full records are maintained wherever they are needed. For instance, survey details relating to land, buildings, sewers, highways and planning schemes, etc. must all be carefully recorded. In planning and building regulations administration, registers must be maintained giving full details of all applications. Openings in highways and their subsequent reinstatement are duly recorded in registers, operated in accordance with the requirements of the Public Utilities Street Works Act, 1950 and often The Street Works Code (Code of Practice) (9).

Local authorities are required to keep sewer maps under the Public Health Act, showing the location, depth and size of each sewer. It is good practice to keep large scale Ordnance sheets on which new buildings are plotted and all services shown in different colours.

Some information, such as rainfall records and water consumption, is best recorded on graphs or charts, to assist with interpretation of statistics. Other methods of presenting statistical information diagrammatically include bar charts, circle or pie diagrams and histograms. Readers requiring basic information on Statistics are referred to the book by Harper (10). It is desirable for engineers to carry pocket note books with them for the recording of information and requests, rather than attempt to commit them to memory.

MANAGEMENT TECHNIQUES

It is imperative that municipal engineers use latest management techniques to secure maximum productivity and efficiency. This is an extremely

wide subject and a number of reference books are listed at the end of this chapter, to which interested readers may like to refer (11).

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APPENDIX I

ENGINEERING DATA

(a) Hydraulic Data

- 1 gallon of water weighs 10 lb.
- 1 ft³ of water occupies 6.24 gallons and weighs 62.4 lb (sea water—64 lb).
- 1 ft head of water = 0.434 lb/in.².
- (1 lb/in.² = 2.3 ft head of water)
- 1 horse power = 33,000 ft lb/min.

(b) Approximate Weights of Materials and Soils in lb/ft³

Earth	95 to 125	Wrought iron	487
Clay	120 to 125	Steel	490
Chalk	140 to 165	Common brickwork	112
Sand	90 to 115	Portland stone	145
Coarse gravel	120	Granite	165
Concrete	130	Fir	35
„ (reinforced)	140	Pitch pine	45
Ashes	40	English oak	50
Cast iron	450	Teak	46

(c) Percentage Increase in Bulk of Soils after Excavation

Sand or gravel	10	Earth or clay	25	Chalk	33
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(d) Quantities of Road Materials in yd²/ton

Tarmacadam, 4 in. consolidated thickness	6
Tarmacadam, 3 in. „ „	8
Tarmacadam, 2 in. „ „	12
Tarmacadam, 1 in. „ „	24
Ashes, 4 in. „ „	6
Ashes, 2 in. „ „	12
Precast concrete paving slabs, 2 in. thick	10

(e) Miscellaneous Information

- 1 yd² of 4½ in. brickwork contains 48 bricks (2½ in.)
- 1 yd² of 9 in. brickwork contains 96 bricks (2½ in.)
- 1 yd² of brickwork in Flemish bond contains 64 facing bricks (2½ in.)
- 1 yd² of brickwork in English bond contains 72 facing bricks (2½ in.)
- 1 Petrograd standard of timber contains 165 ft³
- 1 acre = 4,840 yd²

(f) Weights of Steel Bars in lb/ft

Side or diameter (in.)	Round bars	Square bars
$\frac{3}{16}$	0.094	0.120
$\frac{1}{4}$	0.167	0.213
$\frac{5}{16}$	0.376	0.478
$\frac{3}{8}$	0.668	0.849
$\frac{7}{16}$	1.043	1.328
$\frac{1}{2}$	1.502	1.912
$\frac{5}{8}$	2.044	2.603
1	2.670	3.400
$1\frac{1}{4}$	4.172	5.312
$1\frac{1}{2}$	6.008	7.650
$1\frac{3}{4}$	8.178	10.41
2	10.68	13.60

APPENDIX II

SOME METRIC AND OTHER CONVERSION FACTORS

Length

1 in.	= 25.4 mm
1 ft	= 30.48 cm
1 yd	= 0.9144 m
1 cm	= 0.3937 in.
1 m	= 3.2808 ft
	= 1.0936 yd

Area

1 in. ²	= 6.4516 cm ²
1 ft ²	= 929.03 cm ²
1 yd ²	= 0.836 m ²
1 cm ²	= 0.155 in. ²
1 m ²	= 10.76 ft ²
	= 1.196 yd ²

Volume

1 in. ³	= 16.3870 cm ³
1 ft ³	= 0.0283 m ³
1 yd ³	= 0.766 m ³
1 cm ³	= 0.061 in. ³
1 m ³	= 35.315 ft ³
	= 1.308 yd ³
1 gallon (Imp)	= 1.2 gal (U.S.)
1 litre	= 0.22 gal (Imp)
	= 0.2642 gal (U.S.)

Weight, Mass

1 oz	= 28.35 g
1 lb	= 0.4536 kg
1 kg	= 2.2046 lb
1 slug	= 14.59 kg
	= 32.174 lb
1 kg/cm ²	= 14.22 lb/in. ²
1 lb/in. ³	= 0.0703 kg/cm ³
1 lb/ft ³	= 16.018 kg/m ³
1 cwt	= 112 lb
(hundredweight)	= 50.8 kg
1 ton	= 2,240 lb
	= 1,016 kg

Force, Work

1 pound force = 1 lbf	= 4.448 newton
1 lbf/in. ²	= 0.07 kgf/cm ²
1 lbf/ft ²	= 4.882 kgf/m ²
1 ft lbf	= 0.1383 m kgf

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